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ALTITUDE DEVELOPMENTAL TESTING OF THE J-2 ROCKET ENGINE IN PROPULSION ENGINE TEST CELL (J-4) (TEST J4-1801-09)

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ARO, Inc.

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LARGE ROCKET FACILITY

ARNOLD ENGINEERING DEVELOPMENT CENTER

AIR FORCE SYSTEMS COMMAND

ARNOLD AIR FORCE STATION, TENNESSEE

NOTICES

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FOREWORD

The work reported herein was sponsored by the National Aeronautics and Space Administration (NASA), Marshall Space Flight Center (MSFC) (I-E-J), under System 921E, Project 9194.

The results of the tests presented were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), Arnold Air Force Station, Tennessee, under contract AF40(600)-1200. Program direction was provided by NASA/MSFC; engineering liaison was provided by North American Aviation, Inc., Rocketdyne Division, manufacturer of the J-2 rocket engine, and Douglas Aircraft Company, manufacturer of the S-IVB stage. The testing reported herein was conducted on September 15, 1967, in Propulsion Engine Test Cell (J-4) of the Large Rocket Facility (LRF) under ARO Project No. KA1801. The manuscript was submitted for publication on December 12, 1967.

This technical report has been reviewed and is approved.

Harold Nelson, Jr.
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ABSTRACT

Two nonfiring tests of the Rocketdyne J-2 rocket engine were conducted on September 15, 1967, in Propulsion Engine Test Cell (J-4) of the Large Rocket Facility, Arnold Engineering Development Center. The tests were accomplished during test period J4-1801-09 at pressure altitudes from 97,000 to 106,000 ft. The objectives of the test included the determining of the magnitude of any side forces generated by the flowing of propellants through the engine under propellant tank ullage pressure.

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APPENDIXES

NOMENCLATURE

A	Area, in.^{2}
ASI	Augmented spark igniter
ES	Engine start; designated as the time that helium control and ignition phase solenoids are energized
FM	Frequency modulation
GG	Gas generator
MOV	Main oxidizer valve
STDV	Start tank discharge valve
t_0	Defined as the time at which opening signal is applied to the main-stage control solenoid for test 09A and to the ignition phase solenoid for test 09B
VSC	Vibration safety counts, defined as the time at which engine vibration was in excess of 150 g in a 960- to 6000-Hz frequency range
$\overline{X}$	Arithmetic average

SUBSCRIPTS

f	Force
m	Mass
t	Throat

SECTION I
INTRODUCTION

Testing of the Rocketdyne J-2 rocket engine (S/N J-2052) with an S-IVB battleship stage has been in progress since July 1966 at AEDC, in support of the J-2 engine application on the Saturn IB and Saturn V launch vehicles for the NASA Apollo Program. The two tests reported herein were conducted during test period J4-1801-09 on September 15, 1967, in Propulsion Engine Test Cell (J-4) (Figs. 1 and 2 – Appendix I) of the Large Rocket Facility (LRF) to determine the magnitude of any side forces generated by the flowing of propellants through the engine under propellant tank ullage pressure. These tests were accomplished at pressure altitudes ranging from 97,000 to 106,000 ft (geometric pressure altitude, Z, Ref. 1).

Data collected to accomplish the test objectives are presented herein. The results of the previous test period are reported in Ref. 2.

SECTION II
APPARATUS

2.1 TEST ARTICLE

The test article was a J-2 Rocket Engine (Fig. 3) designed and developed by Rocketdyne Division of North American Aviation, Inc. The engine uses liquid oxygen and liquid hydrogen as propellants, and has a thrust rating of 225,000 lb_f at an oxidizer-to-fuel mixture ratio of 5.5. An S-IVB battleship stage was used to supply propellants to the engine. A schematic of the battleship stage with the J-2 engine is shown in Fig. 4.

A list of the major engine components and engine orifices for this test period are presented in Tables I and II (Appendix II), respectively. No engine modifications and component replacements were performed since the previous test period. The thrust chamber heater blankets were in place during this test period, although they were not utilized.

2.1.1 J-2 Rocket Engine

The J-2 rocket engine (Figs. 3 and 5 through 7, Ref. 3) features the following major components:

1. Thrust Chamber - The tubular-walled, bell-shaped thrust chamber consists of an 18.6-in.-diam combustion chamber (8.0 in. long from the injector mounting to the throat inlet) with a characteristic length (L^*) of 24.6 in., a 170.4-in.^{2} throat area, and a divergent nozzle with an expansion ratio of 27.1. Thrust chamber length (from the injector flange to the nozzle exit) is 107 in. Cooling is accomplished by the circulation of engine fuel flow downward from the fuel manifold through 180 tubes and then upward through 360 tubes to the injector.

2. Thrust Chamber Injector - The injector is a concentric-orificed (concentric fuel orifices around the oxidizer post orifices), porous-faced injector. Fuel and oxidizer injector orifice areas are 25.0 and 16.0 in.^{2}, respectively. The porous material, forming the injector face, allows approximately 3.5 percent of total fuel flow to transpiration cool the face of the injector.

3. Augmented Spark Igniter - The augmented spark igniter unit is mounted on the thrust chamber injector and supplies the initial energy source to ignite propellants in the main combustion chamber. The augmented spark igniter chamber is an integral part of the thrust chamber injector. Fuel and oxidizer are ignited in the combustion area by two spark plugs.

4. Fuel Turbopump - The turbopump is composed of a two-stage turbine-stator assembly, an inducer, and a seven-stage, axial-flow pump. The pump is self lubricated and nominally produces, at rated conditions, a head rise of 35,517 ft (1225 psia) of liquid hydrogen at a flow rate of 8414 gpm for a rotor speed of 26,702 rpm.

5. Oxidizer Turbopump - The turbopump is composed of a two-stage turbine stator assembly and a single-stage centrifugal pump. The pump is self lubricated and nominally produces, at rated conditions, a head rise of 2117 ft (1081 psia) of liquid oxygen at a flow rate of 2907 gpm for a rotor speed of 8572 rpm.

6. Gas Generator - The gas generator consists of a combustion chamber containing two spark plugs, a pneumatically operated control valve containing oxidizer and fuel poppets, and an injector assembly. The oxidizer and fuel poppets provide a fuel

lead to the gas generator combustion chamber. The high-energy gases produced by the gas generator are directed to the fuel turbine and then to the oxidizer turbine (through the turbine crossover duct) before being exhausted into the thrust chamber at an area ratio (A/A_t) of approximately 11.

7. Propellant Utilization Valve - The motor-driven propellant utilization valve is mounted on the oxidizer turbopump and bypasses liquid oxygen from the discharge to the inlet side of the pump to vary engine mixture ratio.

8. Propellant Bleed Valves - The pneumatically operated fuel and oxidizer bleed valves provide pressure relief for the boiloff of propellants trapped between the battleship stage prevalves and main propellant valves at engine shutdown.

9. Integral Hydrogen Start Tank and Helium Tank - The integral tanks consist of a 7258-in.^{3} sphere for hydrogen with a 1000-in.^{3} sphere for helium located within it. Pressurized gaseous hydrogen in the start tank provides the initial energy source for spinning the propellant turbopumps during engine start. The helium tank provides a helium pressure supply to the engine pneumatic control system.

10. Oxidizer Turbine Bypass Valve - The pneumatically actuated oxidizer turbine bypass valve provides control of the fuel turbine exhaust gases directed to the oxidizer turbine in order to control the oxidizer-to-fuel turbine spinup relationship. The fuel turbine exhaust gases which bypass the oxidizer turbine are discharged into the thrust chamber.

11. Main Oxidizer Valve - The main oxidizer valve is a pneumatically-actuated, two-stage, butterfly-type valve located in the oxidizer high pressure duct between the turbopump and the main injector. The first-stage actuator positions the main oxidizer valve at the 14-deg position to obtain initial thrust chamber ignition; the second-stage actuator ramps the main oxidizer valve full open to accelerate the engine to main-stage operation.

12. Main Fuel Valve - The main fuel valve is a pneumatically actuated butterfly-type valve located in the fuel high pressure duct between the turbopump and the fuel manifold.

13. Pneumatic Control Package - The pneumatic control package controls all pneumatically operated engine valves and purges.

14. Electrical Control Assembly - The electrical control assembly provides the electrical logic required for proper sequencing of engine components during operation.

15. Primary and Auxiliary Flight Instrumentation Packages - The instrumentation packages contain sensors required to monitor critical engine parameters. The packages provide environmental control for the sensors.

2.1.2 S-IVB Battleship Stage

The S-IVB battleship stage is approximately 22 ft in diameter and 49 ft long and has a maximum propellant capacity of 46, 000 lb of liquid hydrogen and 199, 000 lb of liquid oxygen. The propellant tanks, fuel above oxidizer, are separated by a common bulkhead. Propellant prevalves, in the low pressure ducts (external to the tanks) interfacing the stage and the engine, retain propellant in the stage until being admitted into the engine to the main propellant valves and serve as emergency engine shutoff valves. Propellant recirculation pumps in both fuel and oxidizer tanks are utilized to circulate propellants through the low pressure ducts and turbopumps before engine start to stabilize hardware temperatures near normal operating levels and to prevent propellant temperature stratification. Vent and relief valve systems are provided for both propellant tanks.

Pressurization of the fuel and oxidizer tanks was accomplished by facility systems using hydrogen and helium, respectively, as the pressurizing gases.

2.2 TEST CELL

Test Cell J-4, Fig. 2, is a vertically oriented test unit designed for static testing liquid-propellant rocket engines and propulsion systems at pressure altitudes of 100, 000 ft. The basic cell construction provides a 1. 5 million-lb_f-thrust capacity. The cell consists of four major components: (1) test capsule, 48 ft in diameter and 82 ft in height, situated at grade level and containing the test article; (2) spray chamber, 100 ft in diameter and 250 ft in depth, located directly beneath the test capsule to provide exhaust gas cooling and dehumidification; (3) coolant water, steam, nitrogen (gaseous and liquid), hydrogen (gaseous and liquid), liquid oxygen and gaseous helium storage and delivery systems for operation of the cell and test article; (4) control building, containing test article controls, test cell controls, and data acquisition equipment. Exhaust machinery is connected with the spray chamber and maintains a low pressure before and after the engine firing and exhaust the products of combustion from the engine firing. Before a firing, the facility steam ejector, in series with the exhaust machinery, provides a pressure altitude of 100, 000 ft in the test capsule. A detailed description of the test cell is presented in Ref. 4.

The battleship stage and the J-2 engine were oriented vertically downward on the centerline of the diffuser-steam ejector assembly. This assembly consisted of a diffuser duct (20 ft in diameter by 150 ft in length), a centerbody steam ejector within the diffuser duct, a diffuser insert (13.5 ft in diameter by 30 ft in length) at the inlet to the diffuser duct, and a gaseous nitrogen annular ejector above the diffuser insert. The diffuser insert was provided for dynamic pressure recovery of the engine exhaust gases and to maintain engine ambient pressure altitude (attained by the steam ejector) during the engine firing. The annular ejector was provided to suppress steam recirculation into the test capsule during steam ejector shutdown. The test cell was also equipped with (1) a gaseous nitrogen purge system for continuously inerting the normal air in-leakage of the cell; (2) a gaseous nitrogen repressurization system for raising test cell pressure, after engine cutoff, to a level equal to spray chamber pressure and for rapid emergency inerting of the capsule; and (3) a spray chamber liquid nitrogen supply and distribution manifold for initially inerting the spray chamber and exhaust ducting and for increasing the molecular weight of the hydrogen-rich exhaust products.

2.3 INSTRUMENTATION

Instrumentation systems were provided to measure engine, stage, and facility parameters. The engine instrumentation was comprised of (1) flight instrumentation for the measurement of critical engine parameters and (2) facility instrumentation which was provided to verify the flight instrumentation and to measure additional engine parameters. The flight instrumentation was provided and calibrated by the engine manufacturer; facility instrumentation was initially calibrated and periodically recalibrated at AEDC. Appendix III contains a list of all measured test parameters and the locations of selected sensing points.

Pressure measurements were made using strain-gage-type pressure transducers. Temperature measurements were made using resistance temperature transducers and thermocouples. Oxidizer and fuel turbopump shaft speeds were sensed by magnetic pickup. Fuel and oxidizer flow rates to the engine were measured by turbine-type flowmeters which are an integral part of the engine. The propellant recirculation flow rates were also monitored with turbine-type flowmeters. Vibrations were measured by accelerometers mounted on the oxidizer injector dome and on the turbopumps. Primary engine and stage valves were instrumented with linear potentiometers and limit switches.

Engine side forces were measured with dual-bridge, strain-gage-type load cells which were laboratory calibrated prior to installation. The load cells were located at 90 deg to each other (see Appendix III, Fig. III-1f) in a horizontal plane 67.25 in. below the engine gimbal center. Before testing, the load cells were electrically calibrated by the resistance substitution method; no physical calibration of the side-force measuring system was conducted.

The data acquisition systems were calibrated by (1) precision electrical shunt resistance substitution for the pressure transducers, and resistance temperature transducer units; (2) voltage substitution for the thermocouples, (3) frequency substitution for shaft speeds and flowmeters; and (4) frequency-voltage substitution for accelerometers.

The types of data acquisition and recording systems used during this test period were (1) a multiple-input digital data acquisition system (MicroSADIC®) scanning each parameter at 40 samples per second and recording on magnetic tape, (2) single-input, continuous-recording FM systems recording on magnetic tape, (3) photographically recording galvanometer oscillographs (4) direct-inking, null balance potentiometer-type X-Y plotters and strip charts, and (5) optical data recorders. Applicable systems were calibrated prior to each test (atmospheric and altitude calibrations). Television cameras, in conjunction with video tape recorders, were used to provide visual coverage during an engine firing, as well as replay capability for immediate examination of unexpected events.

2.4 CONTROLS

Control of the J-2 engine, battleship stage, and test cell systems during the terminal countdown was provided from the test cell control room. A facility control logic network was provided to interconnect the engine control system, major stage systems, the engine safety cutoff system, the observer cutoff circuits, and the countdown sequencer. A schematic of the engine start control logic is presented in Fig. 6. The sequence of engine events for a normal start and shutdown is presented in Figs. 7a and b. Two control logics for sequencing the stage prevalves and recirculation systems with engine start for simulating engine flight start sequences are presented in Figs. 7c and d.

SECTION III
PROCEDURE

Preoperational procedures were begun several hours before the test period. All consumable storage systems were replenished, and engine

inspections, leak checks, and drying procedures were conducted. Propellant tank pressurants and engine pneumatic and purge gas samples were taken to ensure that specification requirements were met. Chemical analysis of propellants was provided by the propellant suppliers. Facility sequence, engine sequence, and engine abort checks were conducted within a 24-hr time period before an engine firing to verify the proper sequence of events. Facility and engine sequence checks consisted of verifying the timing of valves and events to be within specified limits: the abort checks consisted of electrically simulating engine malfunctions to verify the occurrence of an automatic engine cutoff signal. A final engine sequence check was conducted immediately preceding the test period.

Oxidizer dome, gas generator oxidizer injector, and thrust chamber jacket purges were initiated before evacuating the test cell. After completion of instrumentation calibrations at atmospheric conditions, the test cell was evacuated to approximately 0.5 psia with the exhaust machinery, and instrumentation calibrations at altitude conditions were conducted. Immediately before loading propellants on board the vehicle, the cell and exhaust-ducting atmosphere were inerted. At this same time, the cell nitrogen purge was initiated for the duration of the test period, except for the engine firing. The vehicle propellant tanks were then loaded, and the remainder of the terminal countdown was conducted. Temperature conditioning of the thrust chamber was accomplished as required, using the facility-supplied conditioning system. Table III presents the engine purge operations during the terminal countdown and immediately following the engine testing.

SECTION IV
RESULTS AND DISCUSSION

4.1 TEST SUMMARY

Two nonfiring tests were conducted during test J4-1801-09 on September 15, 1967, in support of the S-IVB/S-V J-2 engine developmental program. Thermal conditioning of the thrust chamber was accomplished (Fig. 8) to simulate the predicted flight engine thermal conditions. Test 09A consisted of flowing liquid nitrogen through the thrust chamber oxidizer system for approximately 32 sec. Test 09B consisted of flowing liquid hydrogen through the thrust chamber fuel system for approximately 24 sec.

As stated in Section 2.3, no physical calibration of the force-measuring system was conducted. However, as the magnitude of side

forces involved was less than one percent of the design level of the side-force measuring system, it can be stated that any interaction between the pitch and yaw force measuring components would be negligible. Further, the average levels of measured side forces ($\overline{x}$, a function of propellant tank ullage pressures and facility operation) are of no particular significance; only the change in $\overline{x}$ from pretest to liquid flow conditions is of concern in the subsequent analysis.

Specific test objectives and a brief summary of results obtained are presented as follows:

	Test Objectives	Results
09A	Determine the magnitude of any side forces generated by the engine while flowing liquid nitrogen through the thrust chamber oxidizer system under tank ullage pressure.	Load cell data indicate that side forces attributable to the engine were less than 25 lb_f.
09B	Determine the magnitude of any side forces generated by the engine while flowing liquid hydrogen through the thrust chamber fuel system under tank ullage pressure.	Load cell data indicate that side forces attributable to the engine were less than 25 lb_f.

The presentation of the test results in the following sections will consist of a discussion of each engine test. The data presented will be that recorded by the digital data acquisition system, except as noted. Specific test requirements and results are summarized in Table IV.

4.2 TEST RESULTS

4.2.1 Test J4-1801-09A

Test 09A consisted of flowing liquid nitrogen through the thrust chamber oxidizer system under tank ullage pressure for approximately 32 sec. Oxidizer pump inlet pressure was approximately 35 psia. A summary of test requirements and results is presented in Table IV. Thrust chamber pressure and test cell ambient pressure are shown in Fig. 9.

Side-force data, as recorded on an oscillogram, are shown in Fig. 10. These data are typical 1-sec steady-state time increments as recorded both pretest (approximately t_0 - 5 sec) and during liquid flow (approximately t_0 + 10 sec). The pretest data show the background forces imposed by operation of the test facility steam ejector and water systems. Figure 11 presents histograms of load cell (see Fig. III-1f for orientation) data as recorded by the digital data acquisition system over 5-sec intervals for both pretest and liquid flow conditions; a comparison shows the amplitude change from pretest to liquid flow conditions to be less than 25 lb_f. With reference to Fig. 11, the arithmetic averages pretest for pitch and yaw forces were 115 lb_f with an estimated standard deviation of ±32 lb_f and -49 lb_f with an estimated standard deviation of ±84 lb_f, respectively. The arithmetic averages during liquid flow for pitch and yaw forces were 120 lb_f with an estimated standard deviation of ±24 lb_f and -45 lb_f with an estimated standard deviation of ±83 lb_f, respectively. Results of a power spectral density analysis of load cell data recorded by the FM system show no frequency change from pretest to liquid flow conditions.

Motion picture data showed that, upon shutdown, a ring of solid material fell from the region of the thrust chamber immediately downstream of the throat. Figure 12 shows enlargements of four frames from a 16-mm film exposed at a rate of 200 frames/sec. The four frames in this figure cover a span of approximately 250 ms beginning within 1 sec after shutdown. Analysis showed this ring could have been composed of nitrogen from the thrust chamber injector as the pressure in the thrust chamber approximated the triple-point pressure of nitrogen. This phenomenon was not noted on Test 09B.

4.2.2 Test J4-1801-09B

Test 09B consisted of flowing liquid hydrogen through the thrust chamber fuel system under tank ullage pressure for approximately 24 sec. Fuel pump inlet pressure was approximately 32 psia. A summary of test requirements and results is presented in Table IV. Thrust chamber pressure and test cell ambient pressure are shown in Fig. 13.

Side-force data, as recorded on an oscillogram, are shown in Fig. 14. These data are typical 1-sec steady-state time increments as recorded both pretest (approximately t_0 - 5 sec) and during liquid flow (approximately t_0 + 10 sec). The pretest data show the background forces imposed by operation of the test facility steam ejector and water systems. Figure 15 presents histograms of load cell (see Fig. III-1f for orientation) data as recorded by the digital data acquisition system over 5-sec

intervals for both pretest and liquid flow conditions; a comparison shows the amplitude change from pretest to liquid flow conditions to be less than 25 lb_f. With reference to Fig. 15, the arithmetic averages pretest for pitch and yaw forces were 145 lb_f with an estimated standard deviation of ±32 lb_f and -37 lb_f with an estimated standard deviation of ±65 lb_f, respectively. The arithmetic averages during liquid flow for pitch and yaw forces were 136 lb_f with an estimated standard deviation of ±32 lb_f and -52 lb_f with an estimated standard deviation of ±57 lb_f, respectively. Results of a power spectral density analysis of load cell data recorded by the FM system shows no frequency change from pretest to liquid flow conditions.

SECTION V
SUMMARY OF RESULTS

The results of two nonfiring tests of the J-2 engine conducted on September 15, 1967, in Propulsion Engine Test Cell (J-4) are summarized as follows:

1. Load cell data indicate that side forces generated by the flowing of liquid nitrogen under tank ullage pressure through the thrust chamber oxidizer system were less than 25 lb_f.
2. Load cell data indicate that side forces generated by the flowing of liquid hydrogen under tank ullage pressure through the thrust chamber fuel system were less than 25 lb_f.

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1. Dubin, M., Sissenwine, N., and Wexler, H. "U. S. Standard Atmosphere, 1962." December 1962.
2. Counts, H. J. "Altitude Developmental Testing of the J-2 Rocket Engine in Propulsion Engine Test Cell (J-4) (Test J4-1801-05)." AEDC-TR-67-208, October 1967.
3. "J-2 Rocket Engine, Technical Manual Engine Data." R-3825-1, August 1965.
4. Test Facilities Handbook (6th Edition). "Large Rocket Facility, Vol. 3." Arnold Engineering Development Center, November 1966.

APPENDIXES

I. ILLUSTRATIONS
II. TABLES
III. INSTRUMENTATION

Fig. 1 Test Cell J-4 Complex

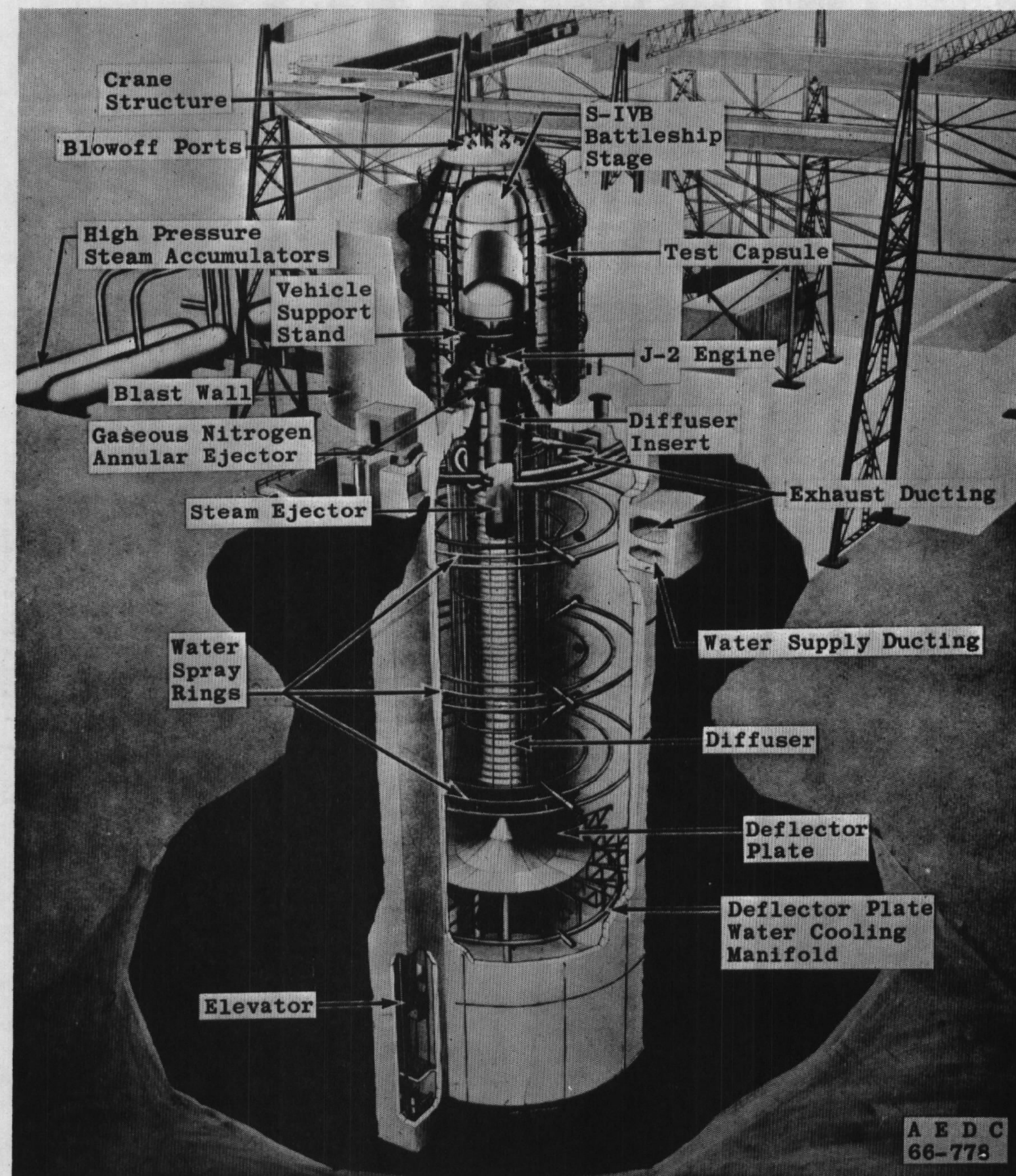


Fig. 2 Test Cell J-4, Artist's Conception

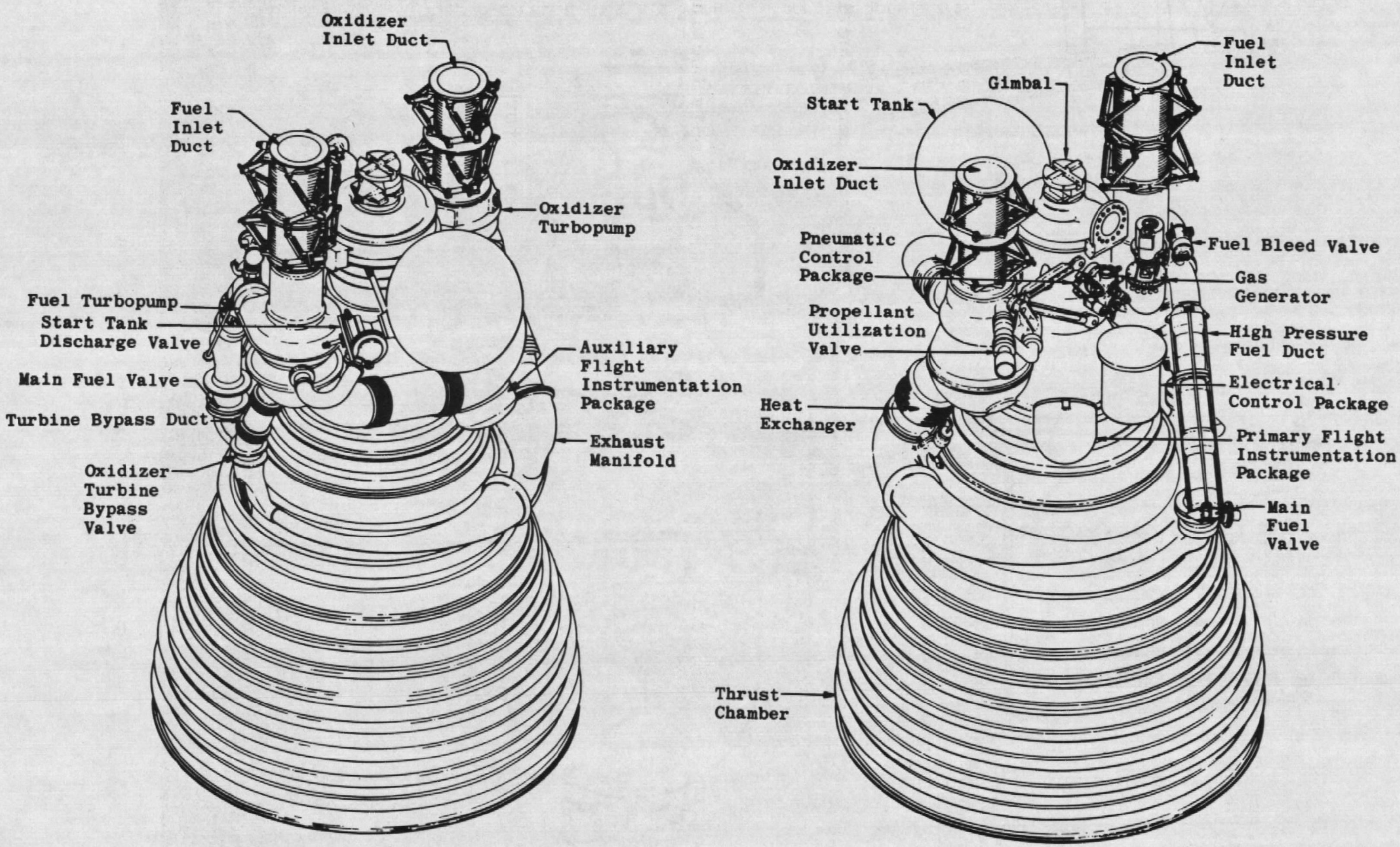


Fig. 3 Engine Details

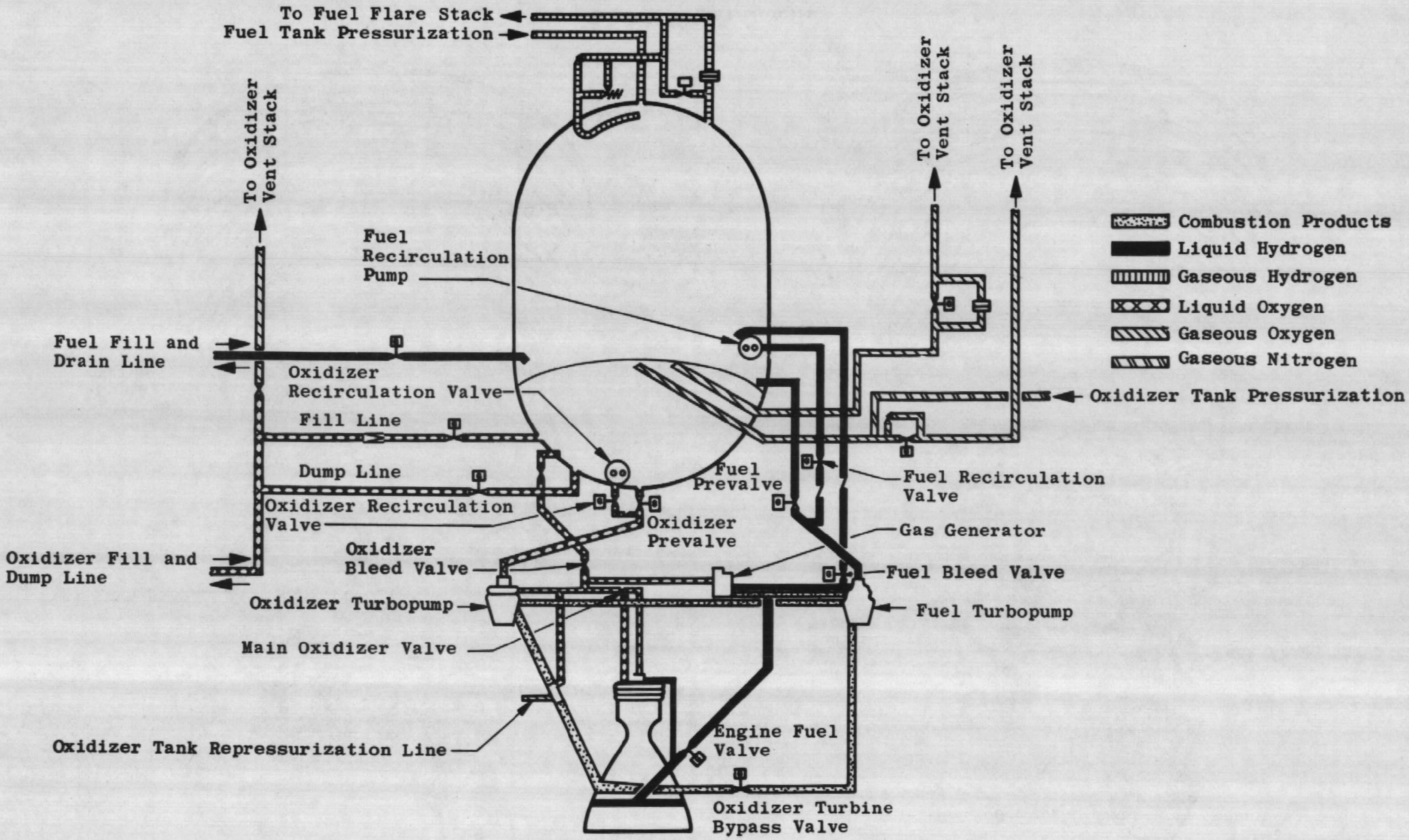


Fig. 4 S-IVB Battleship Stage (J-2 Engine Schematic)

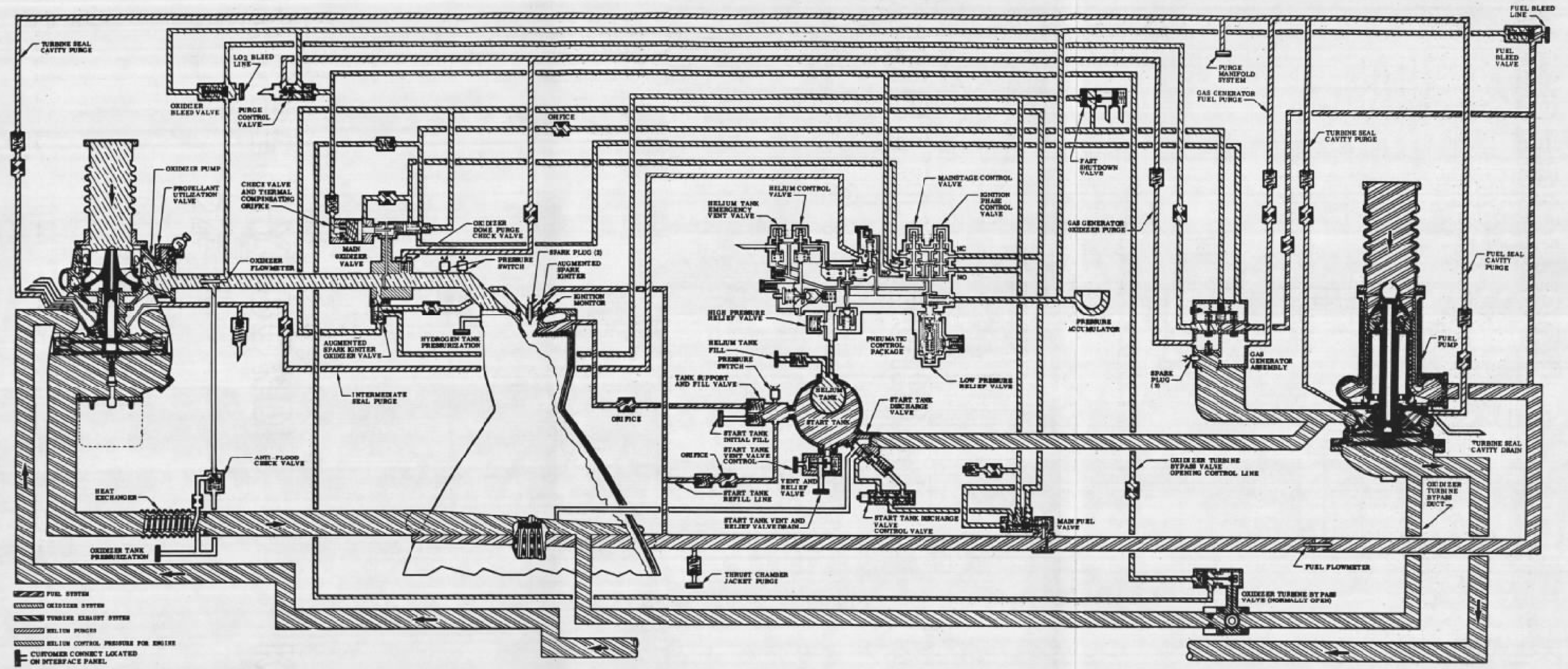


Fig. 5 Engine Schematic

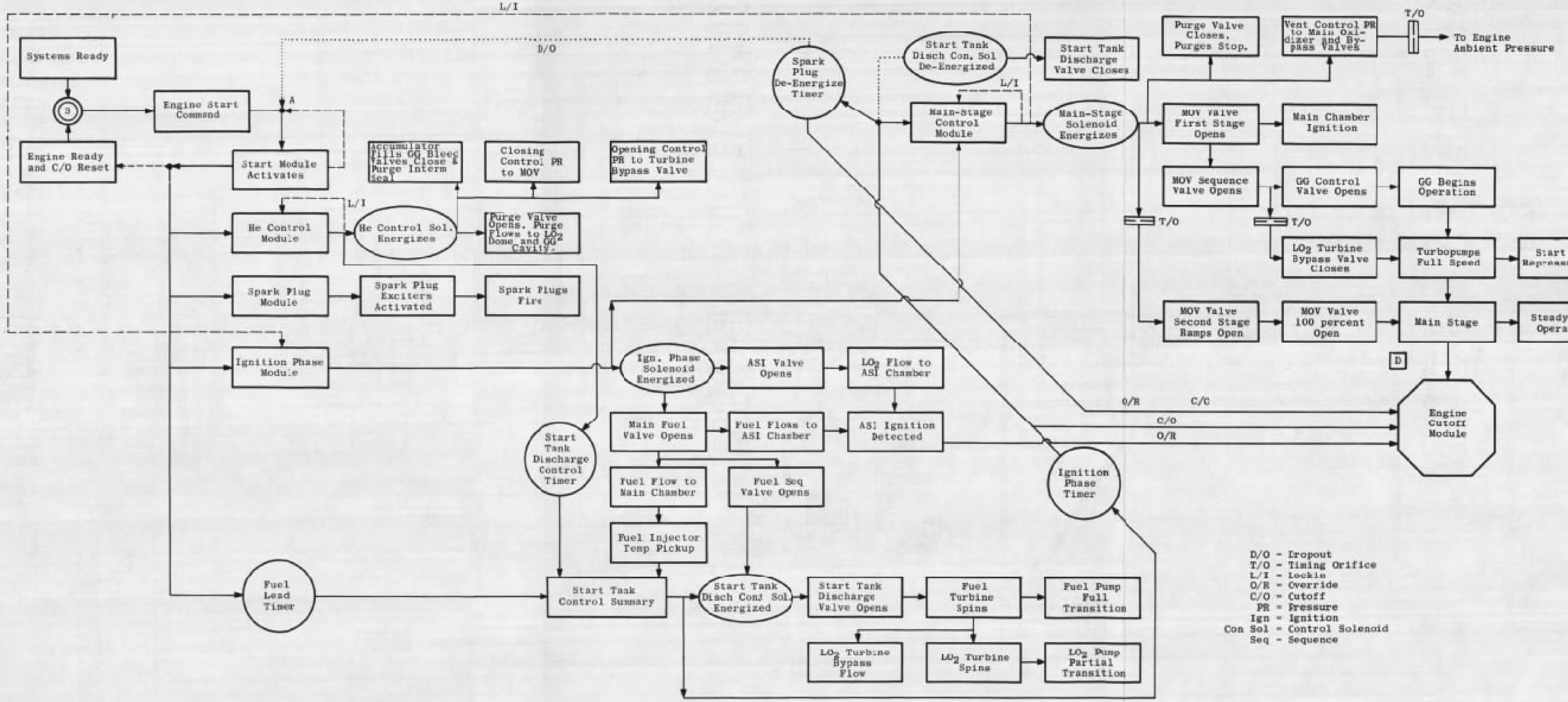
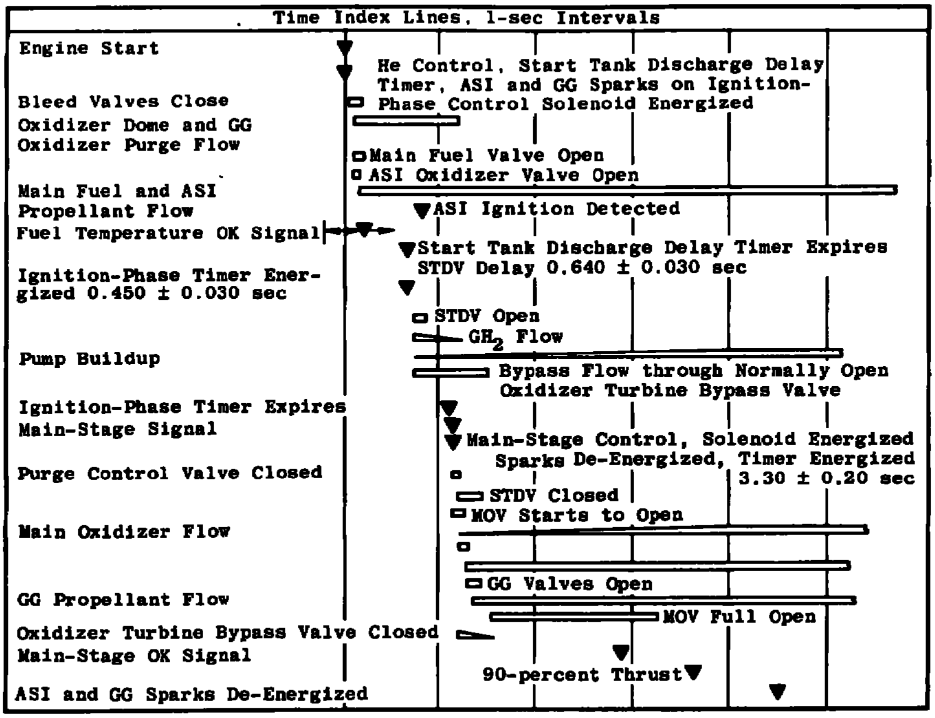
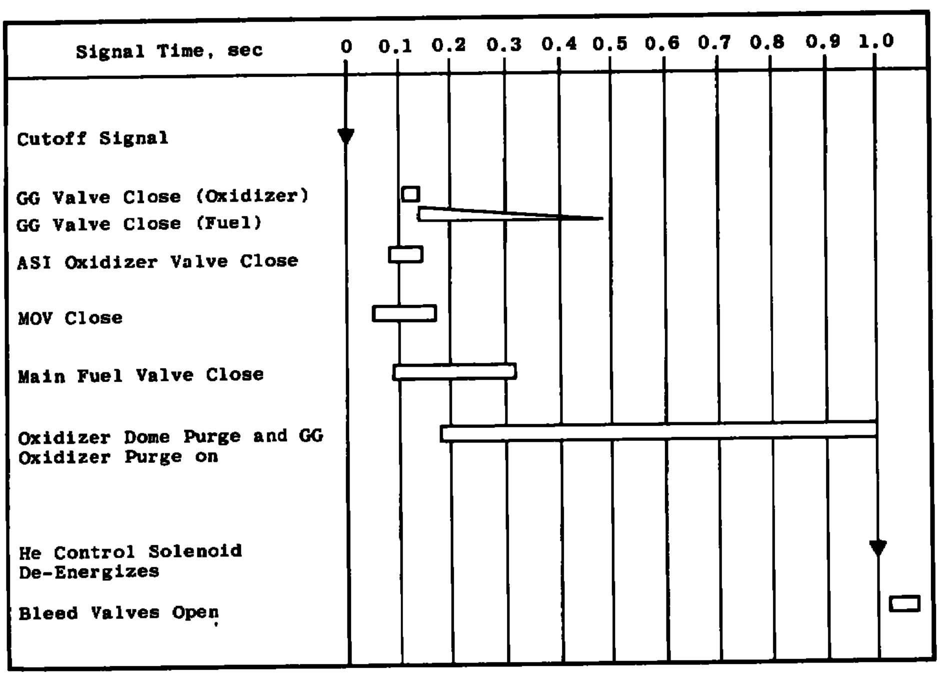


Fig. 6 Engine Start Logic Schematic

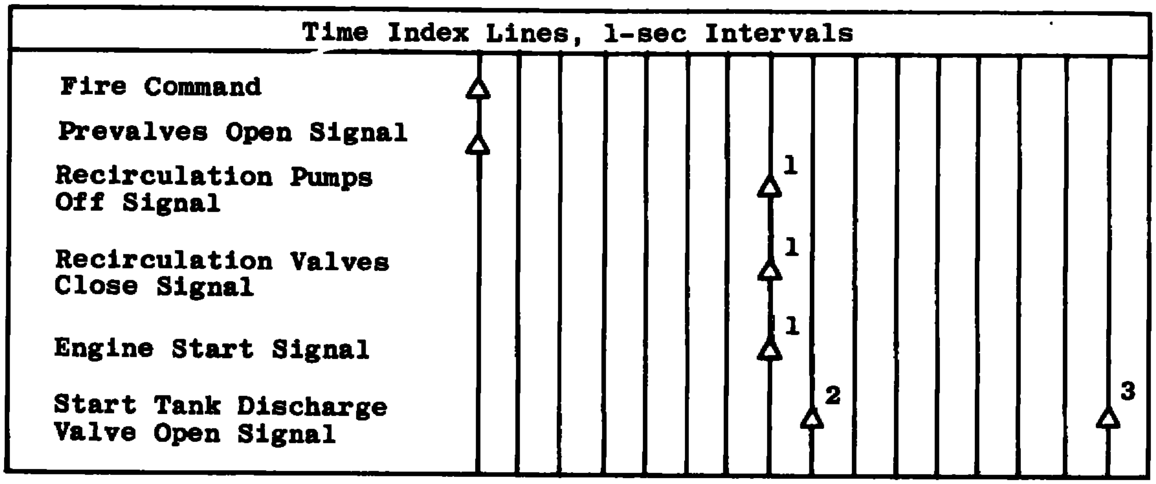


a. Start Sequence



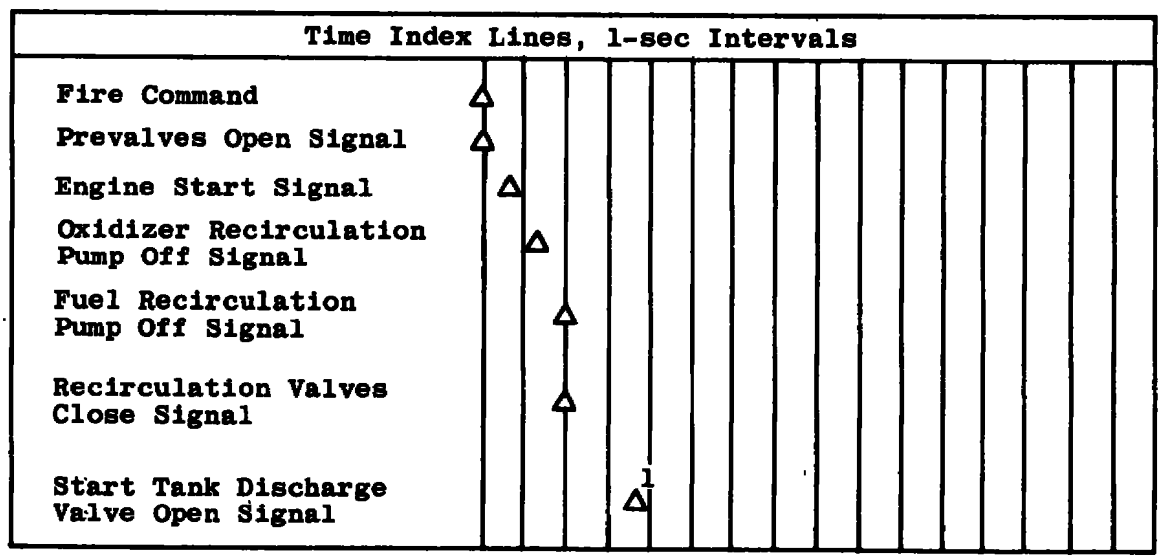
b. Shutdown Sequence

Fig. 7 Engine Start and Shutdown Sequence



[1]Nominal Occurrence Time (Function of Prevalves Opening Time)
[2]One-sec Fuel Lead (S-II/S-V and S-IVB/S-IB)
[3]Eight-sec Fuel Lead (S-IVB/S-V and S-IB Orbital Restart)

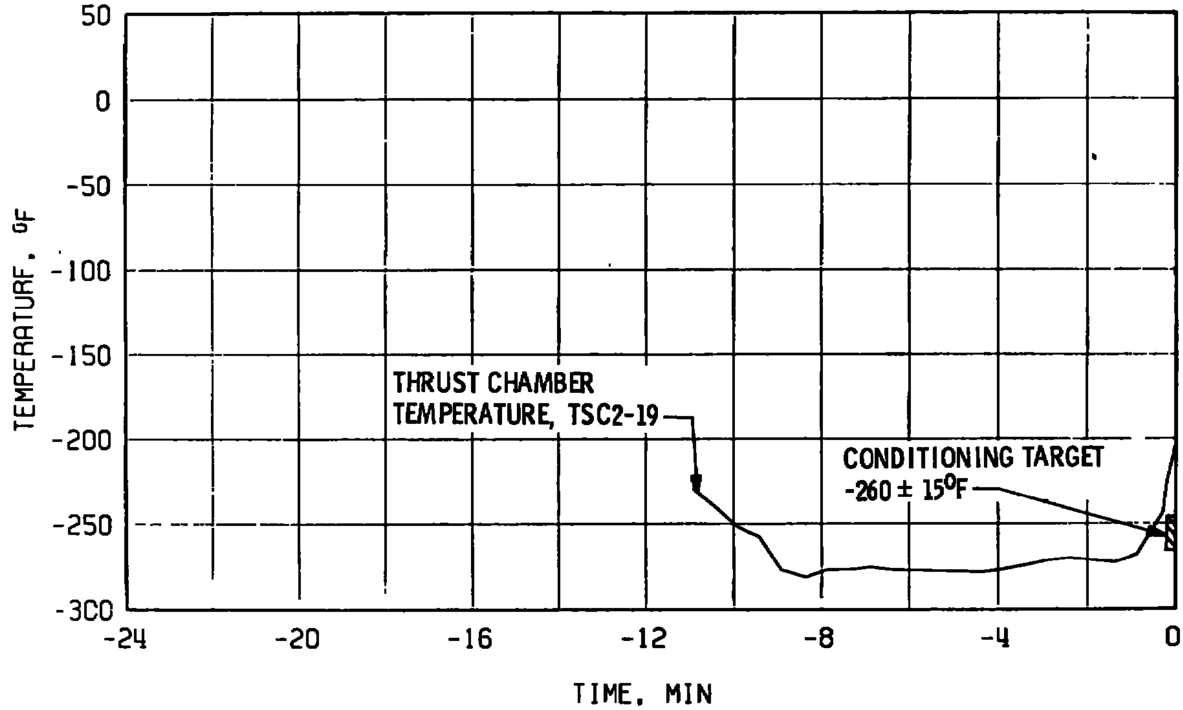
c. "Normal" Start Sequence



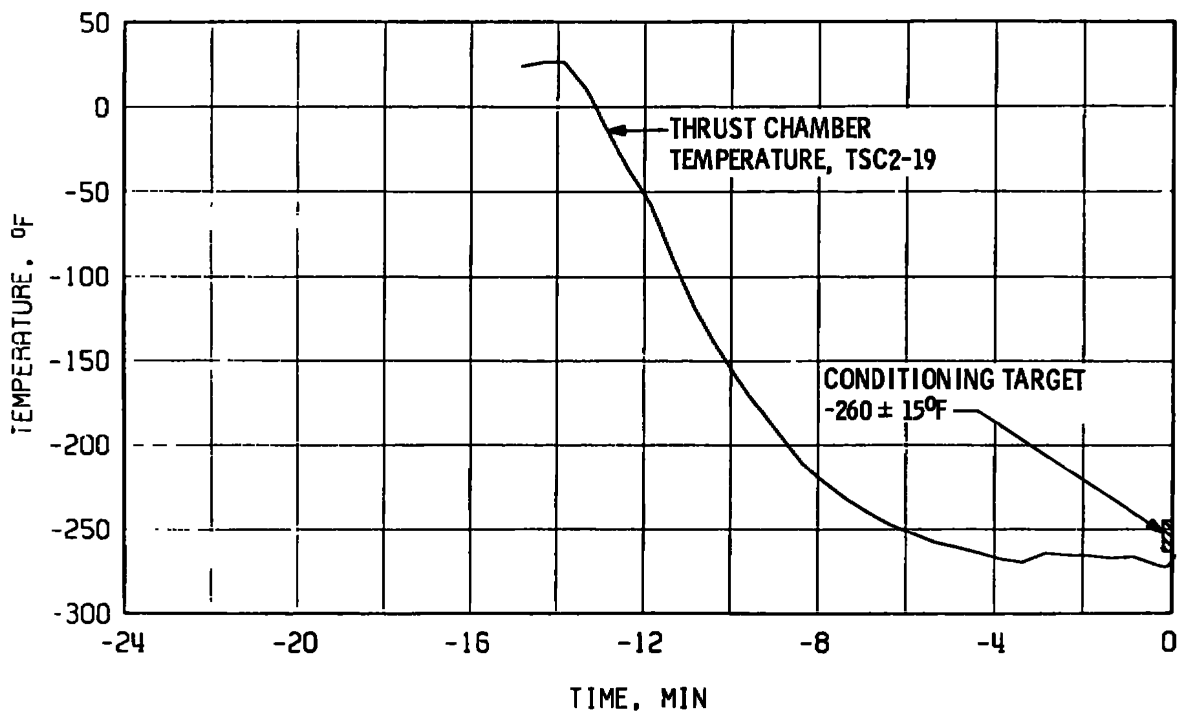
[1]Three-sec Fuel Lead (S-IVB/S-V First Burn)

d. "Auxiliary" Start Sequence

Fig. 7 Concluded



a. Test 09A



b. Test 09B

Fig. 8 Thermal Conditioning History of Thrust Chamber

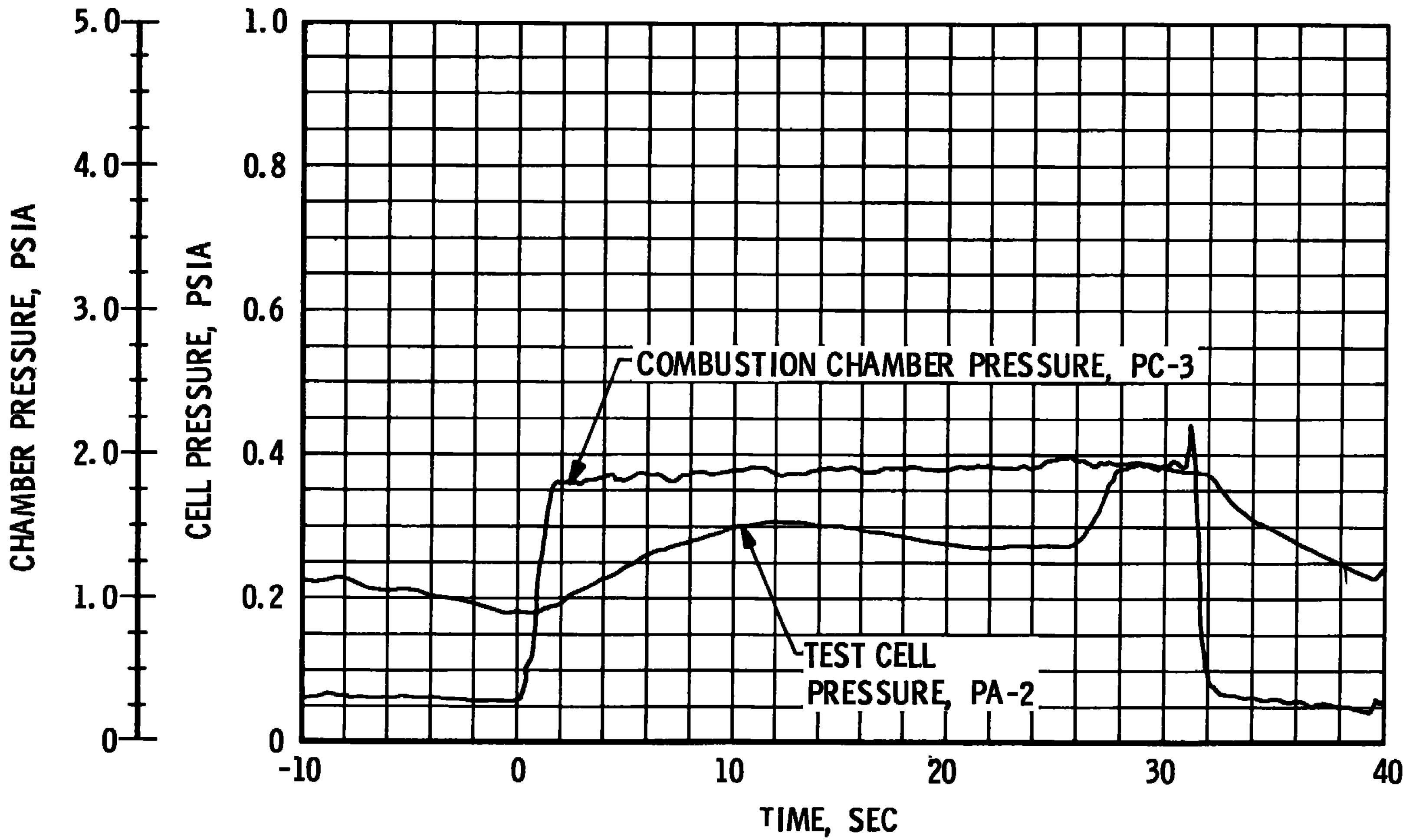
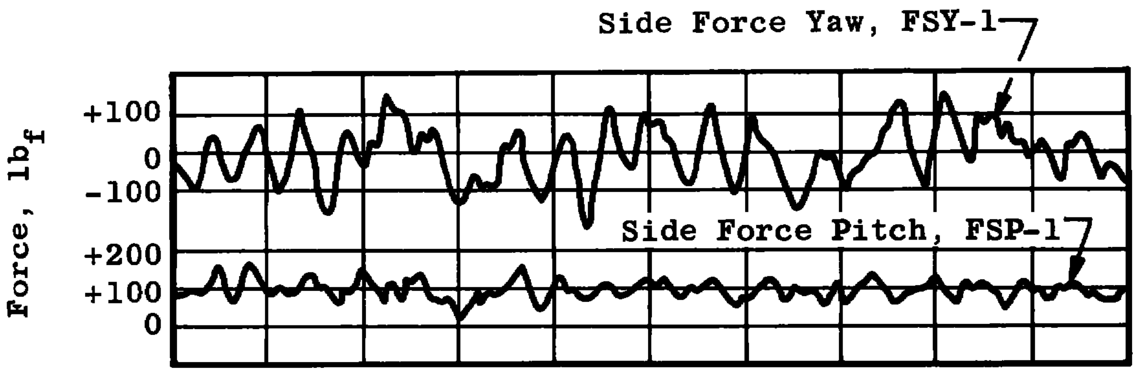
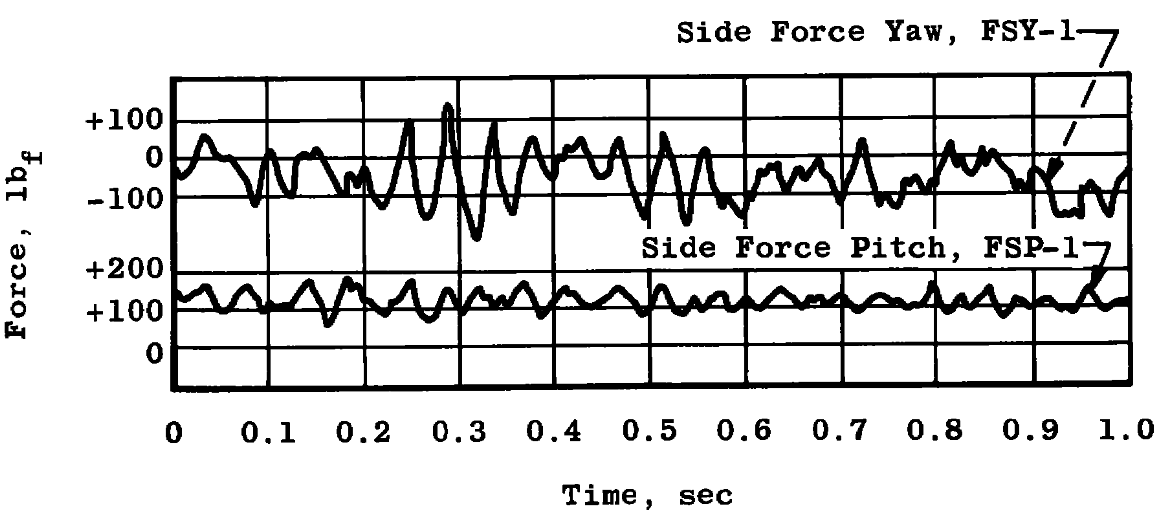


Fig. 9 Engine Ambient and Combustion Chamber Pressure, Test 09A

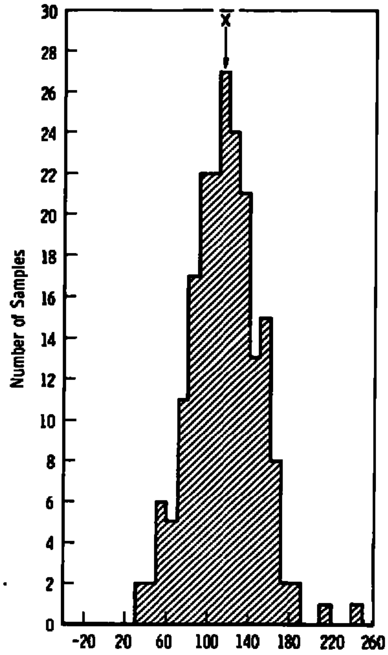


a. Pretest

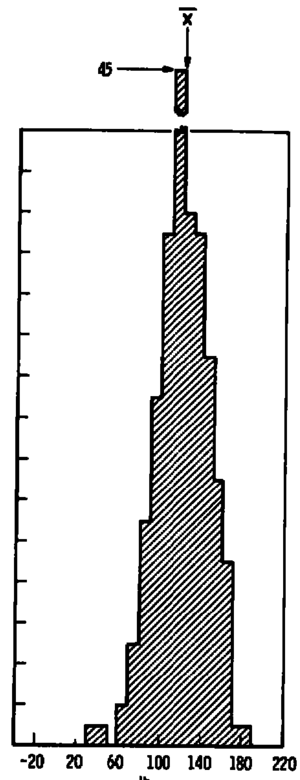


b. Liquid Flow

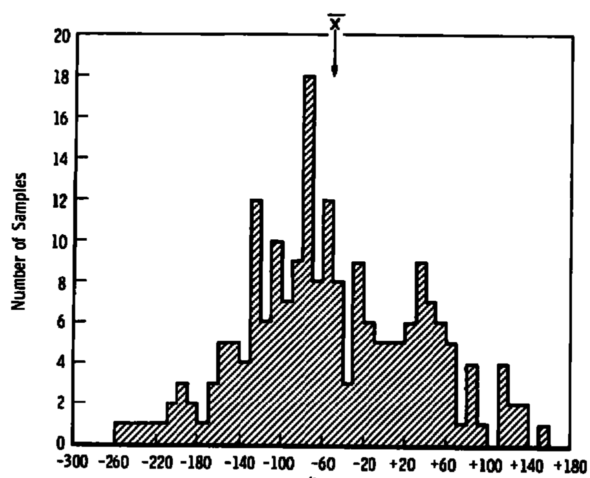
Fig. 10 Oscillogram Overlay of Side Forces, Test 09A



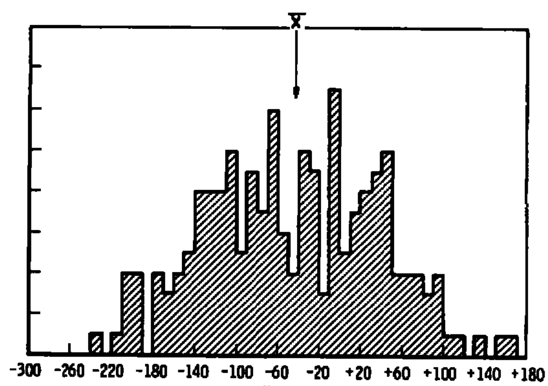
a. Side Force Pitch, FSP-1, Pretest



b. Side Force Pitch, FSP-1, Liquid Flow



c. Side Force Yaw, FSY-1, Pretest



d. Side Force Yaw, FSY-1, Liquid Flow

Fig. 11 Histogram of Side Forces, Test 09A

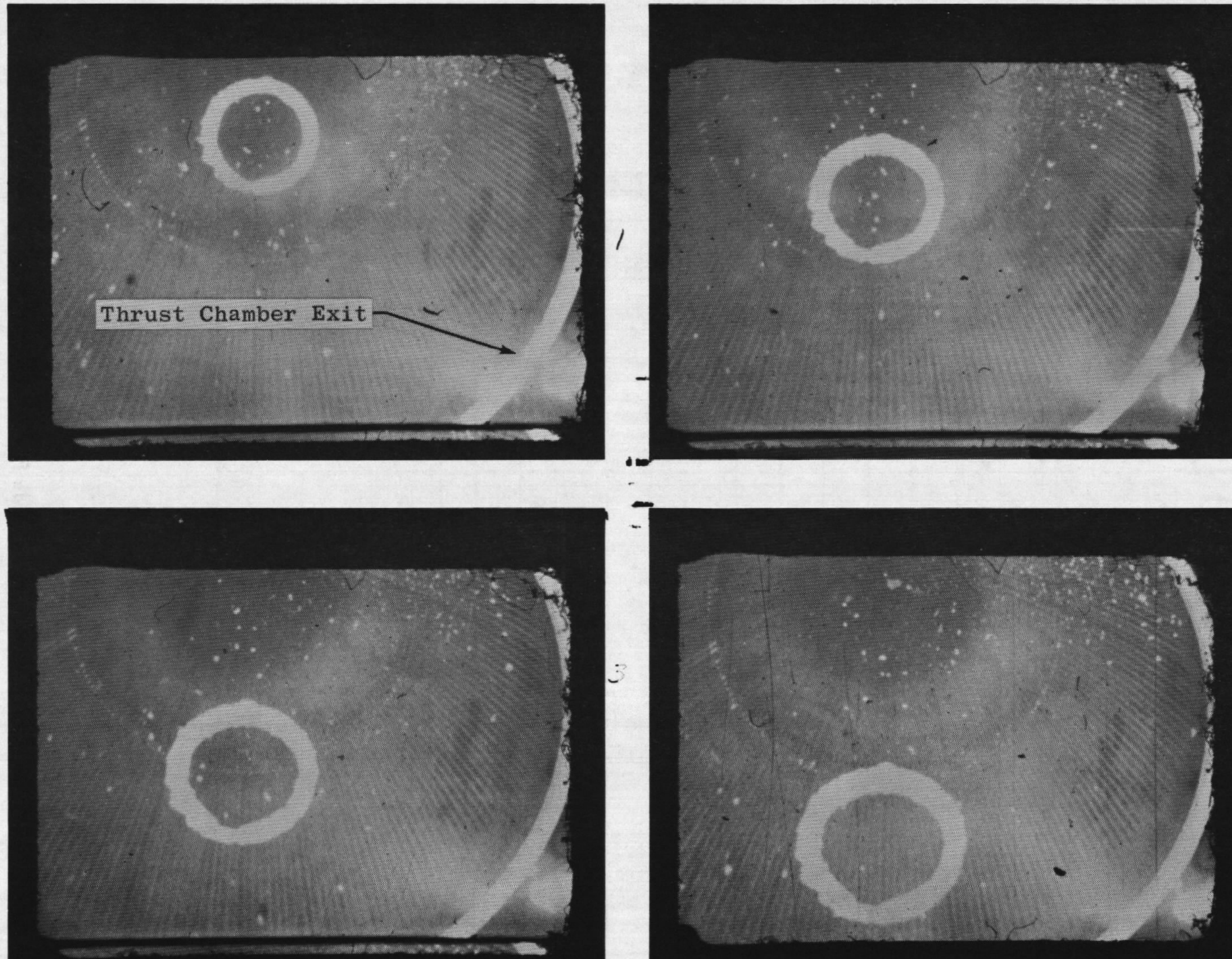


Fig. 12 Internal View of Thrust Chamber Looking Upstream, Test 09A

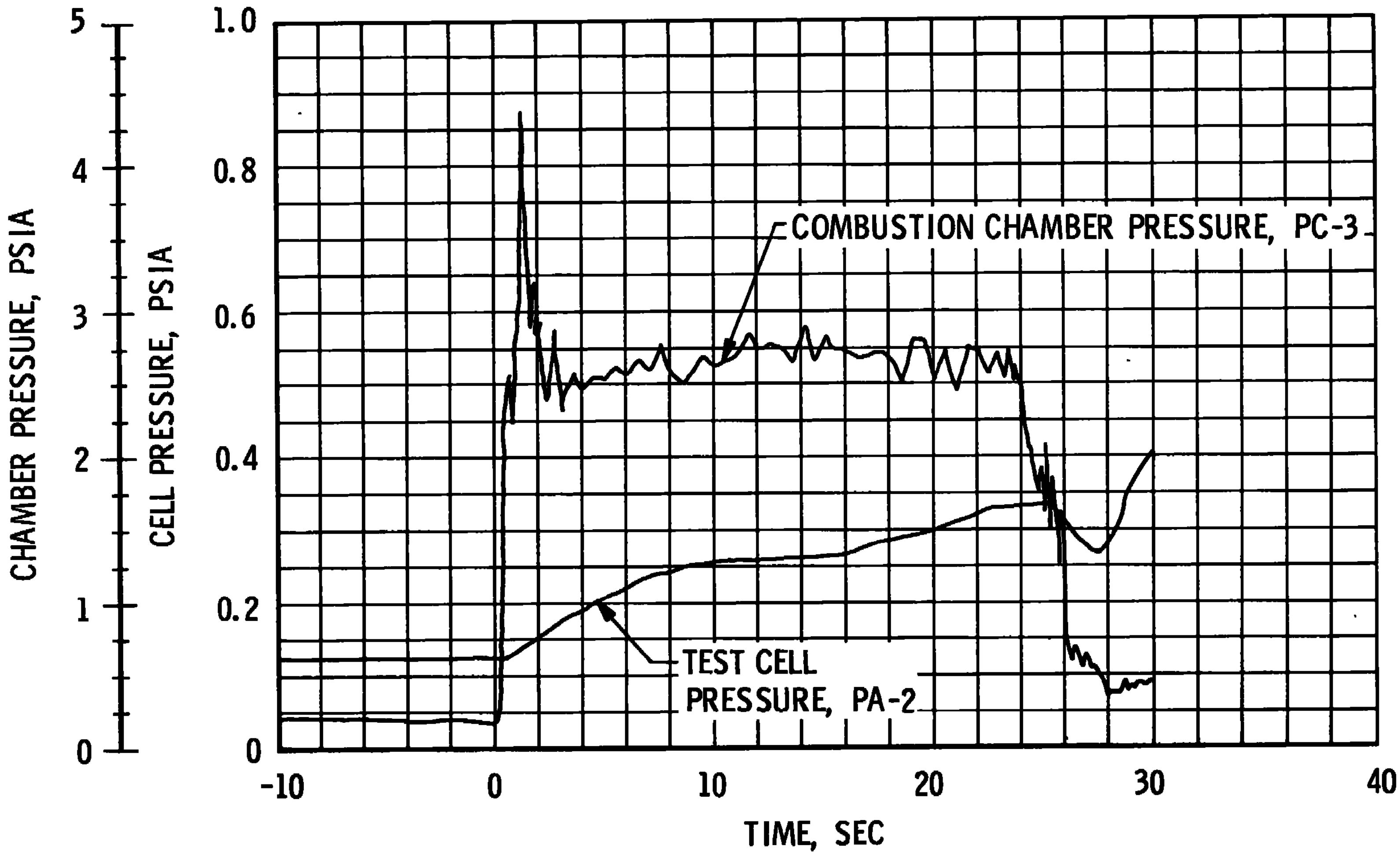
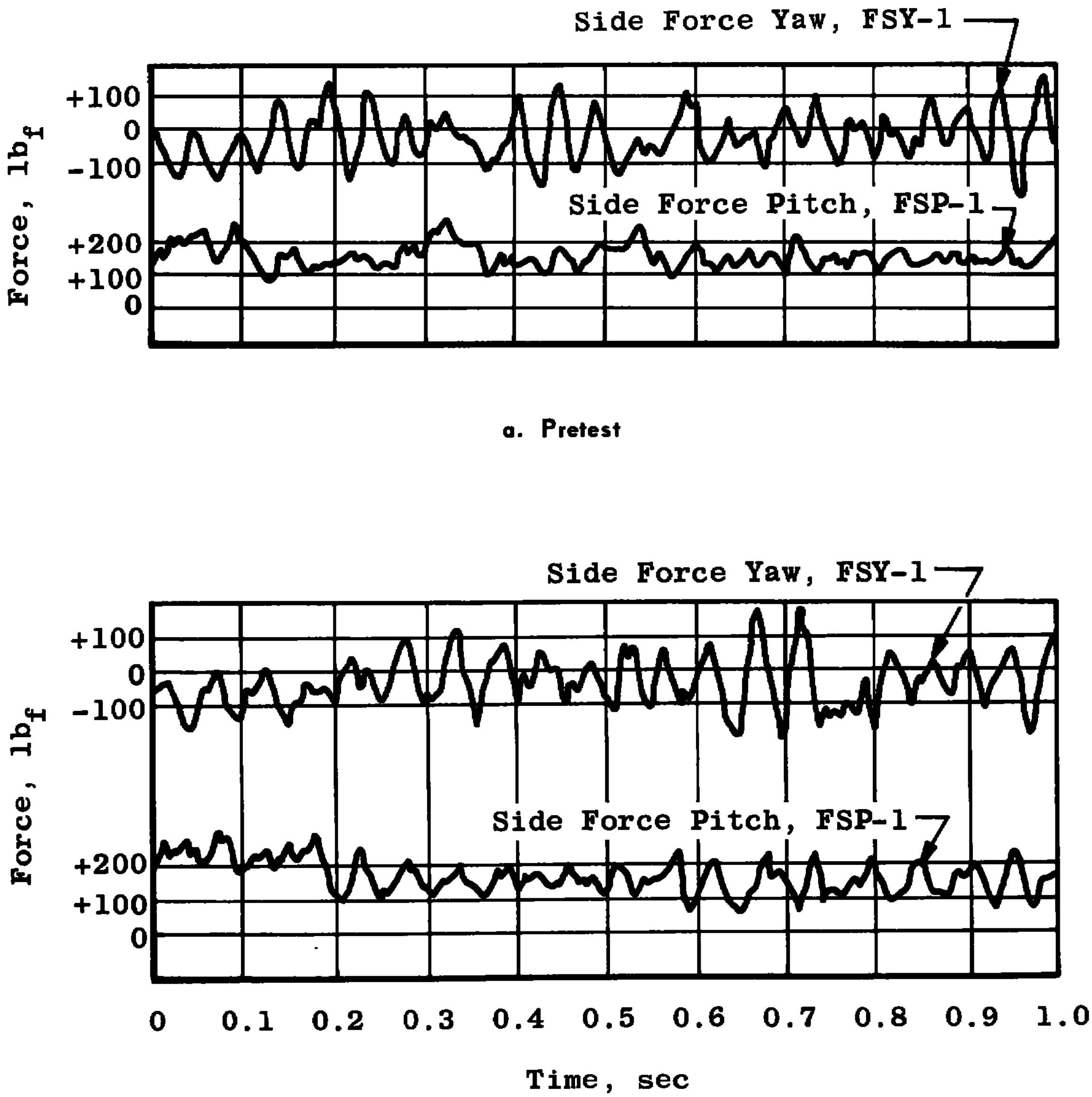


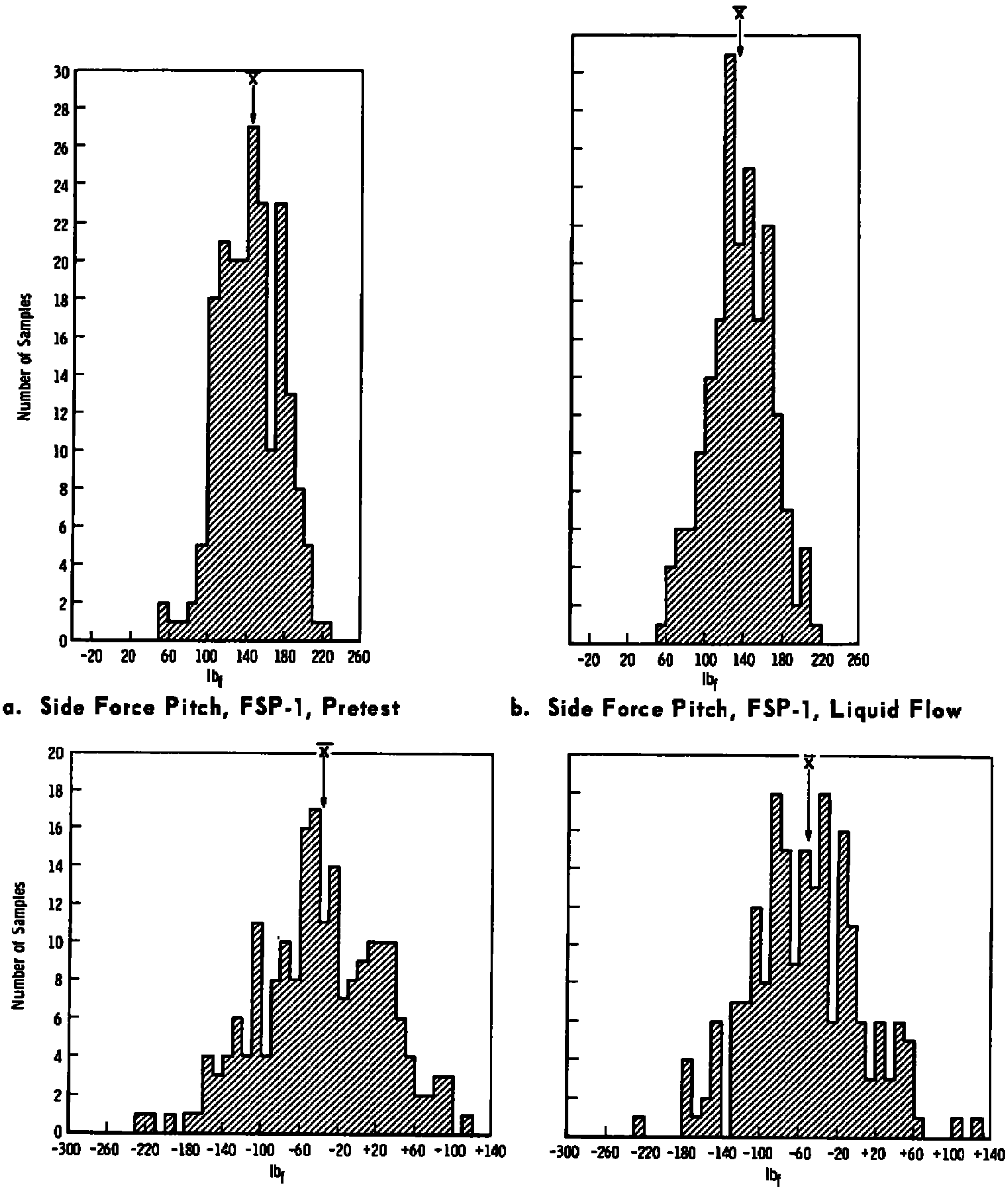
Fig. 13 Engine Ambient and Combustion Chamber Pressure, Test 09B



a. Pretest

b. Liquid Flow

Fig. 14 Oscillogram Overlay of Side Forces, Test 09B



a. Side Force Pitch, FSP-1, Pretest

b. Side Force Pitch, FSP-1, Liquid Flow

c. Side Force Yaw, FSY-1, Pretest

d. Side Force Yaw, FSY-1, Liquid Flow

Fig. 15 Histogram of Side Forces, Test 09B

TABLE I
MAJOR ENGINE COMPONENTS

Part Name	P/N	S/N
Thrust Chamber Body	206600-31	4076553
Thrust Chamber Injector Assembly	208021-11	4084917
Fuel Turbopump Assembly	459000-181	4062085
Oxidizer Turbopump Assembly	458175-71	6623549
Start Tank	303439	0064
Augmented Spark Igniter	206280-21	3661349
Gas Generator Fuel Injector and Combustor	308360-11	2008734
Pneumatic Control Assembly	558130-41	4092999
Electrical Control Package	502670-11	4081748
Primary Flight Instrumentation Package	703685	4078716
Auxiliary Flight Instrumentation Package	703680	4078718
Main Fuel Valve	409120	4056924
Main Oxidizer Valve	411031	4089563
Gas Generator Control Valve	309040	4074190
Start Tank Discharge Valve	306875	4079062
Oxidizer Turbine Bypass Valve	409940	4048489
Propellant Utilization Valve	251351-11	4068944
Main-Stage Control Valve	558069	8313568
Ignition Phase Control Valve	558069	8275775
Helium Control Valve	106012000	3793-0
Start Tank Vent and Relief Valve	557828-X2	4046446
Helium Tank Vent Valve	106012000	342277
Fuel Bleed Valve	309034	4077749
Oxidizer Bleed Valve	309029	4077746
Augmented Spark Igniter Oxidizer Valve	308880	4077205
P/A Purge Control Valve	557823	4073021
Start Tank Fill/Refill Valve	558000	4079001
Fuel Flowmeter	251225	4077752
Oxidizer Flowmeter	251216	4074114
Fuel Injector Temperature Transducer	NA5-27441	12401
Restartable Ignition Detect Probe	XEOR915389	211

TABLE II
SUMMARY OF ENGINE ORIFICES

Orifice Name	Part Number	Diameter, in.	Installation Date	Comments
Gas Generator Fuel	RD-251-4107	0.480	8-18-67	FTP Replacement
Gas Generator Oxidizer	RD-251-4106	0.281	8-18-67	FTP Replacement
Oxidizer Turbine By-pass Valve	RD-273-8002	1.571	7-31-67	RFD-AEDC 58-67
Main Oxidizer Valve Closing Control	410437	8.65 scfm	8-28-67	RFD-AEDC 17-1-67
Oxidizer Turbine Exhaust	RD-251-9004	10.0	1-18-67	Size Verification
Augmented Spark Igniter Oxidizer	406361 None	0.137 0.125	8-10-67	RFD-AEDC 62-67

TABLE III
ENGINE PURGE AND COMPONENT CONDITIONING SEQUENCE

Turbopump and Gas Generator Purge (Purge Manifold System)	Helium, 82 - 125 psia 50 - 200°F (Nominal) 6 scfm at Customer Connect
Oxidizer Dome and Gas Generator Liquid Oxygen Injector (Engine Pneumatic System)	Nitrogen, 400 ± 25 psig 50 - 200°F (Minimum) 230 scfm
Oxidizer Dome (Facility Line to Port CO3A)	Nitrogen; 400 - 450 psig 100 - 200°F (Nominal) 200 scfm
Oxidizer Turbopump Intermediate Seal Cavity (Engine Pneumatic System)	Helium, 400 ± 25 psig Ambient Temperature 2600 - 7000 scfm
Thrust Chamber Jacket (Customer Connect) Panel	Helium, 40 - 60 psig 50 - 200°F (Nominal) 60 scfm
	Helium, 12 - 14 psig 50 - 200°F (Nominal) 10 scfm
Thrust Chamber Temperature Conditioning	Helium, 1000 psig -300°F to Ambient 10 - 20 lb_m/min
Pump Inlet Pressure and Temperature Conditioning	Oxidizer, 35 to 48 psia -298 to -280°F Fuel; 28 to 46 psia -424 to -410°F

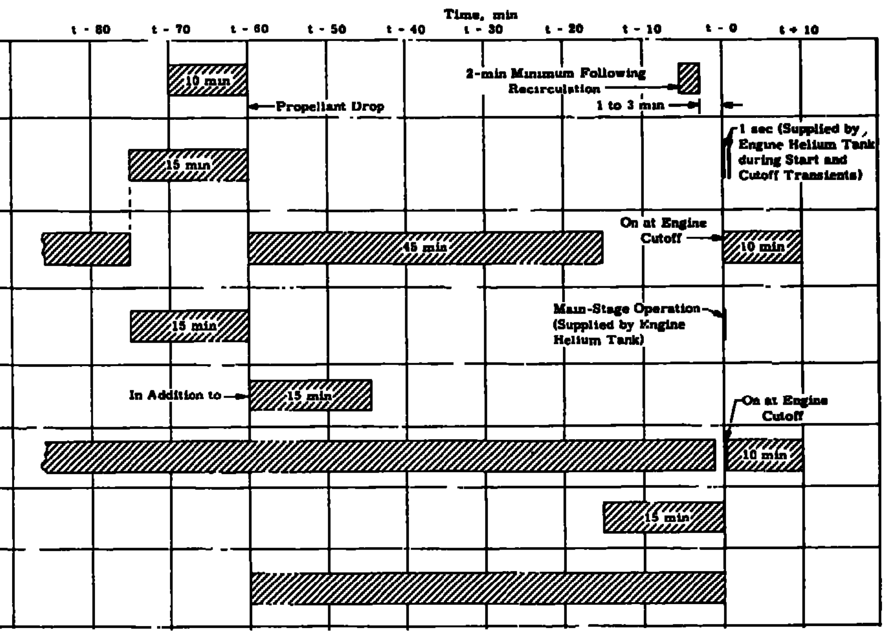


TABLE IV
SUMMARY OF TEST REQUIREMENTS AND RESULTS

Test Number, J4-1801-		09A		09B	
		Target	Actual	Target	Actual
Time of Day, hr/Test Date		1052 hr September 15, 1967		1125 hr September 15, 1967	
Pressure Altitude, ft		100,000	97,000	100,000	106,000
Test Duration, sec		20	31.9	20	23.6
Fuel Pump Inlet Conditions at t_0	Pressure, psia	---	---	32.0	31.9
	Temperature, °F	---	---	-420.2	-419.7
Oxidizer Pump Inlet Conditions at t_0	Pressure, psia	34.0	35.1	---	---
	Temperature, °F	-317.2	-314.9	---	---
Start Tank Conditions at Engine Start	Pressure, psia	---	---	---	---
	Temperature, °F	---	---	---	---
Helium Tank Conditions at Engine Start	Pressure, psia	---	---	---	---
	Temperature, °F	---	---	---	---
Thrust Chamber Temperature Conditions at Engine Start, °F	Throat	-260	---	-260	---
	Average	---	---	---	---
Crossover Duct Temperature at Engine Start, °F	TFTD-2	---	---	---	---
	TFTD-3	---	---	---	---
	TFTD-8	---	---	---	---
Main Oxidizer Valve Closing Control Line Temperature at Engine Start, °F		---	---	---	---
Main Oxidizer Valve Second-Stage Actuator Temperature at Engine Start, °F		---	---	---	---
Pneumatic Control Package Temperature at Engine Start, °F		---	---	---	---
Fuel Lead Time, sec		---	---	---	---
Propellant in Engine Time, min		60	97	60	33
Propellant Recirculation Time, min		10	10	10	10
Prevalve Sequencing Logic		Normal	Normal	Normal	Normal
Bootstrap Line Temperature at Engine Start, °F	TOBS	---	---	---	---
	TOBS	---	---	---	---
	TOBS	---	---	---	---
Start Tank Discharge Valve Body Temperature at Engine Start, °F		---	---	---	---
Gas Generator Control Valve Body Temperature at Engine Start, °F		---	---	---	---
Vibration Safety Count Duration (msec) and Occurrence Time (sec) from t_0		--- / ---	--- / ---	--- / ---	--- / ---
Gas Generator Outlet Temperature, °F	Initial Peak	---	---	---	---
	Overshoot	---	---	---	---
Main Chamber Ignition (P_c = 100 psia) Time, sec (Ref. t_0)		---	---	---	---
Main Oxidizer Valve Second-Stage Initial Movement, sec (Ref. t_0)		---	---	---	---
Main-Stage Pressure No. 2 "O.K.", sec (Ref. t_0)		---	---	---	---
550-psia Chamber Pressure Attained, sec (Ref. t_0)		---	---	---	---
Propellant Utilization Valve Position at Engine Start, deg Engine Start/t_0 + 10 sec		Null / Null	Null / Null	Null / Null	Null / Null

APPENDIX III
INSTRUMENTATION

The instrumentation for AEDC Test J4-1801-09 is tabulated in Table III-1. The location of selected major engine instrumentation is shown in Fig. III-1.

TABLE III-1
LIST OF ENGINE INSTRUMENTATION

AEDC Code	Parameter	Tap No.	Range	Micro-SADIC	Magnetic Tape	Oscillo-graph	Strip Chart	X-Y Plotter
	Current		amp					
ICC	Control		0 to 30	x		x		
IIC	Ignition		0 to 30	x		x		
	Event							
EECL	Engine Cutoff Lockin		On/Off	x		x		
EECO	Engine Cutoff Signal		On/Off	x	x	x		
EES	Engine Start Command		On/Off	x		x		
EFBVC	Fuel Bleed Valve Closed Limit		Open/Closed	x				
EFJT	Fuel Injector Temperature OK		On/Off	x		x		
EFPVC/O	Fuel Pre-Valve Closed/Open Limit		Closed/Open	x		x		
EHCS	Helium Control Solenoid		On/Off	x		x		
EID	Ignition Detected		On/Off	x		x		
EIPCS	Ignition Phase Control Solenoid		On/Off	x		x		
EMCS	Main-Stage Control Solenoid		On/Off	x		x		
EMP-1	Main-Stage Pressure No. 1		On/Off	x		x		
EMP-2	Main-Stage Pressure No. 2		On/Off	x		x		
EOBVC	Oxidizer Bleed Valve Closed Limit		Open/Closed	x				
EOPVC	Oxidizer Pre-Valve Closed Limit		Closed	x		x		
EOPVO	Oxidizer Pre-Valve Open Limit		Open	x		x		
ESTDCS	Start Tank Discharge Control Solenoid		On/Off	x	x	x		
RASIS-1	Augmented Spark Igniter Spark No. 1		On/Off			x		
RASIS-2	Augmented Spark Igniter Spark No. 2		On/Off			x		
RGGS-1	Gas Generator Spark No. 1		On/Off			x		
RGGS-2	Gas Generator Spark No. 2		On/Off			x		
	Flows		gpm					
QF-1A	Fuel	PFF	0-9000	x		x		
QF-2	Fuel	PFFA	0-9000	x	x	x		
QF-2SD	Fuel Flow Stall Approach Monitor		0-9000	x		x		
QFRP	Fuel Recirculation		0-160	x				
QO-1A	Oxidizer	POF	0-3000	x		x		
QO-2	Oxidizer	POFA	0-3000	x	x	x		
QORP	Oxidizer Recirculation		0-50	x			x	
	Forces		lb_f					
RSP-1	Side Load (Pitch)		±20,000	x	x	x		
FSY-1	Side Load (Yaw)		±20,000	x	x	x		
	Heat Flux		$\frac{w}{Sr.-cm^2}$					
RTCEP	Radiation Thrust Chamber Exhaust Plume		0-7	x				
	Position		Percent Open					
LFVT	Main Fuel Valve		0 to 100	x		x		
LGGVT	Gas Generator Valve		0 to 100	x		x		
LOTBVT	Oxidizer Turbine Bypass Valve		0 to 100	x		x		
LOVT	Main Oxidizer Valve		0 to 100	x	x	x		
LPUTOP	Propellant Utilization Valve		0 to 100	x		x	x	
LSTDVT	Start Tank Discharge Valve		0 to 100	x		x		
	Pressure		psia					
PA1	Test Cell		0-0.5	x		x		
PA2	Test Cell		0-1.0	x	x			
PA3	Test Cell		0-5.0	x			x	
PC-1P	Thrust Chamber	CG1	0-1000	x			x	
PC-2	Thrust Chamber	CG1	0-15	x		x		
PC-3	Thrust Chamber	CG1A	0-50	x	x	x		
PCASI-2	Augmented Spark Igniter Chamber	IG1	0-1000	x				
PCGG-1P	Gas Generator Chamber Pressure		0-1000	x	x	x		
PCGG-2	Gas Generator Chamber	GG1A	0-1000	x				

TABLE III-1 (Continued)

AEDC Code	Parameter	Tap No.	Range	Micro-SADIC	Magnetic Tape	Oscillo-graph	Strip Chart	X-Y Plotter
	Pressure		psia					
PFASIJ	Augmented Spark Igniter Fuel Injection		0-1000	x				
PFJ-1A	Main Fuel Injection	CF2	0-1000	x		x		
PFJ-2	Main Fuel Injection	CF2A	0-1000	x	x			
PFJGG-1A	Gas Generator Fuel Injection	GF4	0-1000	x				
PFJGG-2	Gas Generator Fuel Injection	GF4	0-1000	x		x		
PFMI	Fuel Jacket Inlet Manifold	CF1	0-2000	x				
PFOI-1A	Fuel Tapoff Orifice Outlet	HF2	0-1000	x				
PFPC-1A	Fuel Pump Balance Piston Cavity	PF5	0-1000	x				
PFPD-1P	Fuel Pump Discharge	PF3	0-1500	x				
PFPD-2	Fuel Pump Discharge	PF2	0-1500	x	x	x		
PFPI-1	Fuel Pump Inlet		0-100	x				x
PFPI-2	Fuel Pump Inlet		0-200	x				x
PFPI-3	Fuel Pump Inlet		0-200		x	x		
PFPS-1P	Fuel Pump Interstage	PF6	0-200	x				
PFRPO	Fuel Recirculation Pump Outlet		0-60	x				
PFRPR	Fuel Recirculation Pump Return		0-50	x				
PFST-1P	Fuel Start Tank	TF1	0-1500	x		x		
PFST-2	Fuel Start Tank	TF1	0-1500	x				x
PFUT	Fuel Tank Ullage		0-100	x				
PFVI	Fuel Tank Pressurization Line Nozzle Inlet		0-1000	x				
PFVL	Fuel Tank Pressurization Line Nozzle Throat		0-1000	x				
PGBNI	Bypass Nozzle Inlet	TG8	0-200	x				
PHECMO	Pneumatic Control Module Outlet		0-750	x				
PHEOP	Oxidizer Recirculation Pump Purge		0-150	x				
PHES	Helium Supply		0-5000	x				
PHET-1P	Helium Tank	NN1	0-3500	x		x		
PHET-2	Helium Tank	NN1	0-3500	x				x
PHRO-1A	Helium Regulator Outlet	NN2	0-750	x	x			
POBSC	Oxidizer Bootstrap Conditioning		0-50	x				
POBV	Gas Generator Oxidizer Bleed Valve	GO2	0-2000	x				
POJ-1A	Main Oxidizer Injection	CO3	0-1000	x				
POJ-2	Main Oxidizer Injection	CO3A	0-1000	x		x		
POJGG-1A	Gas Generator Oxidizer Injection	GO5	0-1000	x		x		
POJGG-2	Gas Generator Oxidizer Injection	GO5	0-1000	x				
POPBC-1A	Oxidizer Pump Bearing Coolant	PO7	0-500	x				
POPD-1P	Oxidizer Pump Discharge	PO3	0-1500	x				
POPD-2	Oxidizer Pump Discharge	PO2	0-1500	x	x	x		
POPI-1	Oxidizer Pump Inlet		0-1000	x				x
POPI-2	Oxidizer Pump Inlet		0-200	x				x
POPI-3	Oxidizer Pump Inlet		0-100			x		
POPSC-1A	Oxidizer Pump Primary Seal Cavity	PO6	0-50	x				
PORPO	Oxidizer Recirculation Pump Outlet		0-115	x				
PORPR	Oxidizer Recirculation Pump Return		0-100	x				
POTI-1A	Oxidizer Turbine Inlet	TG3	0-200	x				
POTO-1A	Oxidizer Turbine Outlet	TG4	0-100	x				
POUT	Oxidizer Tank Ullage		0-100	x				

TABLE III-1 (Continued)

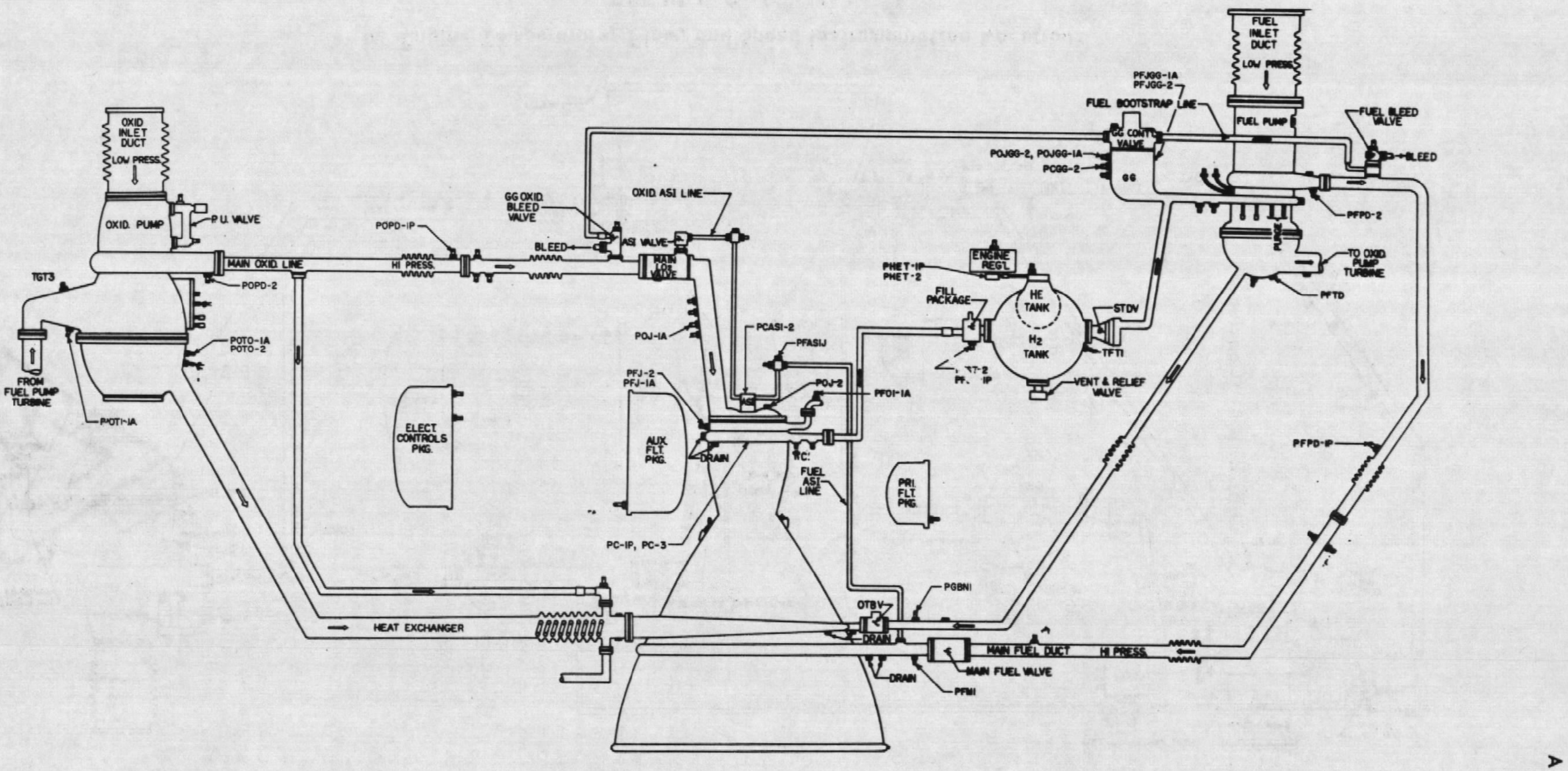
AEDC Code	Parameter	Tap No	Range	Micro-SADIC	Magnetic Tape	Oscillograph	Strip Chart	X-Y Plotter
	Pressure		psia					
POVCC	Main Oxidizer Valve Closing Control		0-500	x	x			
POVI	Oxidizer Tank Pressurization Line Nozzle Inlet		0-1000	x				
POVL	Oxidizer Tank Pressurization Line Nozzle Throat		0-1000	x				
PPUVI-1A	Propellant Utilization Valve Inlet	PO8	0-1000	x				
PPUVO-1A	Propellant Utilization Valve Outlet	PO9	0-500	x				
PTCFJP	Thrust Chamber Fuel Jacket Purge		0-100	x				
PTCP	Thrust Chamber Purge		0-15	x				
PTPP	Turbopump and Gas Generator Purge		0-250	x				
	Speeds		rpm					
NFP-1P	Fuel Pump	PFV	0-30, 000	x	x	x		
NFRP	Fuel Recirculation Pump		0-15, 000	x				
NOP-1P	Oxidizer Pump	POV	0-12, 000	x	x	x		
NORP	Oxidizer Recirculation Pump		0-15, 000	x				
	Temperatures		°F					
TA1	Test Cell (North)		-50 to +800	x				
TA2	Test Cell (East)		-50 to +800	x				
TA3	Test Cell (South)		-50 to +800	x				
TA4	Test Cell (West)		-50 to +800	x				
TAIP-1A	Auxiliary Instrument Package		-300 to +200	x				
TBHR-1	Helium Regulator Body (North Side)		-100 to -50	x				
TBHR-2	Helium Regulator Body (South Side)		-100 to +50	x				
TBPM	Bypass Manifold		-325 to +200	x				
TBSC	Oxidizer Bootstrap Conditioning		-350 to +150	x				
TCLC	Main Oxidizer Valve Closing Control Line Conditioning		-325 to +200	x				
TECP-1P	Electrical Controls Package	NST1A	-300 to +200	x			x	
TFASIJ	Augmented Spark Igniter Fuel Injection	IFT1	-425 to +100	x		x		
TFASIL-1	Augmented Spark Igniter Line		-300 to -200	x			x	
TFASIL-2	Augmented Spark Igniter Line		-300 to +300	x			x	
TFBV-1A	Fuel Bleed Valve	GFT1	-425 to -375	x				
TFD-1	Fire Detection		0 to 1000	x			x	
TFJ-1P	Main Fuel Injection	CFT2	-425 to +250	x	x	x		
TFPB-1A	Fuel Pump Bearing		-425 to -325	x				
TFPD-1P	Fuel Pump Discharge	PFT1	-425 to -400	x	x	x		
TFPD-2	Fuel Pump Discharge	PFT1	-425 to -400	x				
TFPDD	Fuel Pump Discharge Duct		-320 to +300	x				
TFPI-1	Fuel Pump Inlet		-425 to -400	x				x
TFPI-2	Fuel Pump Inlet		-425 to -400	x				x
TFRPO	Fuel Recirculation Pump Outlet		-425 to -410	x				
TFRPR	Fuel Recirculation Pump Return Line		-425 to -250	x				
TFRT-1	Fuel Tank		-425 to -410	x				
TFRT-2	Fuel Tank		-425 to -410	x				
TFST-1P	Fuel Start Tank	TFT1	-350 to +100	x				
TFST-2	Fuel Start Tank	TFT1	-350 to +100	x				x
TFTD-1	Fuel Turbine Discharge Duct		-200 to +800	x				
TFTD-1R	Fuel Turbine Discharge Collector		-200 to +900	x				
TFTD-2	Fuel Turbine Discharge Duct		-200 to +1000	x			x	

TABLE III-1 (Continued)

AEDC Code	Parameters	Tap No.	Range	Micro-SADIC	Magnetic Tape	Oscillo-graph	Strip Chart	X-Y Plotter
	Temperatures		°F					
TFTD-3	Fuel Turbine Discharge Duct		-200 to +1000	x			x	
TFTD-3R	Fuel Turbine Discharge Line		-200 to +900	x				
TFTD-4	Fuel Turbine Discharge Duct		-200 to +1000	x				
TFTD-4R	Fuel Turbine Discharge Line		-200 to +900	x				
TFTD-5	Fuel Turbine Discharge Duct		-200 to +1400	x				
TFTD-6	Fuel Turbine Discharge Duct		-200 to +1400	x				
TFTD-7	Fuel Turbine Discharge Duct		-200 to +1400	x				
TFTD-8	Fuel Turbine Discharge Duct		-200 to +1400	x			x	
TFTI-1P	Fuel Turbine Inlet	TFT1	0 to 1800	x			x	
TFTO	Fuel Turbine Outlet	TFT2	0 to 1800	x				
TGGO-1A	Gas Generator Outlet	GGT1	0 to 1800	x	x	x		
THET-1P	Helium Tank	NNT1	-350 to +100	x				x
TMOVC	Main Oxidizer Valve Actuator Conditioning		-325 to +200	x				
TNODP	LOX Dome Purge		0 to -300	x				
TOBS-1	Oxidizer Bootstrap Line		-300 to +250	x				
TOBS-2	Oxidizer Bootstrap Line		-300 to +250	x				
TOBS-2A	Oxidizer Bootstrap Line		-300 to +250	x				
TOBS-2B	Oxidizer Bootstrap Line		-300 to +250	x				
TOBS-3	Oxidizer Bootstrap Line		-300 to +250	x				
TOBS-4	Oxidizer Bootstrap Line		-300 to +250	x				
TOBSCI	Oxidizer Bootstrap Conditioning Inlet		0 to 100	x				
TOBSCO	Oxidizer Bootstrap Conditioning Outlet		0 to 100	x				
TOBV-1A	Oxidizer Bleed Valve	GOT2	-300 to -250	x				
TOPB-1A	Oxidizer Pump Bearing Coolant	POT4	-300 to -250	x				
TOPD-1P	Oxidizer Pump Discharge	POT3	-300 to -250	x	x	x	x	
TOPD-2	Oxidizer Pump Discharge	POT3	-300 to -250	x				
TOPDS	Oxidizer Pump Discharge Skin		-300 to -100	x				
TOPI-1	Oxidizer Pump Inlet		-300 to -270	x				x
TOPI-2	Oxidizer Pump Inlet		-300 to -270	x				x
TORPO	Oxidizer Recirculation Pump Outlet		-300 to -250	x				
TORPR	Oxidizer Recirculation Pump Return		-300 to -140	x				
TORT-1	Oxidizer Tank		-300 to -287	x				
TORT-3	Oxidizer Tank		-300 to -287	x				
TOTI-1P	Oxidizer Turbine Inlet	TGT3	0 to 1200	x			x	
TOTO-1P	Oxidizer Turbine Outlet	TGT4	0 to 1000	x				
TOVL	Oxidizer Tank Pressurization Line Nozzle Throat		-300 to +100	x				
TPCC	Prechill Controller		-425 to -300	x				
TRIP-1P	Primary Instrument Package		-300 to +200	x				
TPPC	Pneumatic Package Conditioning		-325 to +200	x				
TSC2-1	Thrust Chamber Skin		-300 to +500	x				
TSC2-2	Thrust Chamber Skin		-300 to +500	x				
TSC2-3	Thrust Chamber Skin		-300 to +500	x				
TSC2-4	Thrust Chamber Skin		-300 to +500	x				
TSC2-5	Thrust Chamber Skin		-300 to +500	x				
TSC2-6	Thrust Chamber Skin		-300 to +500	x				
TSC2-7	Thrust Chamber Skin		-300 to +500	x				
TSC2-8	Thrust Chamber Skin		-300 to +500	x				
TSC2-9	Thrust Chamber Skin		-300 to +500	x				
TSC2-10	Thrust Chamber Skin		-300 to +500	x				
TSC2-11	Thrust Chamber Skin		-300 to +500	x				
TSC2-12	Thrust Chamber Skin		-300 to +500	x				
TSC2-13	Thrust Chamber Skin		-300 to +500	x			x	
TSC2-14	Thrust Chamber Skin		-300 to +500	x				

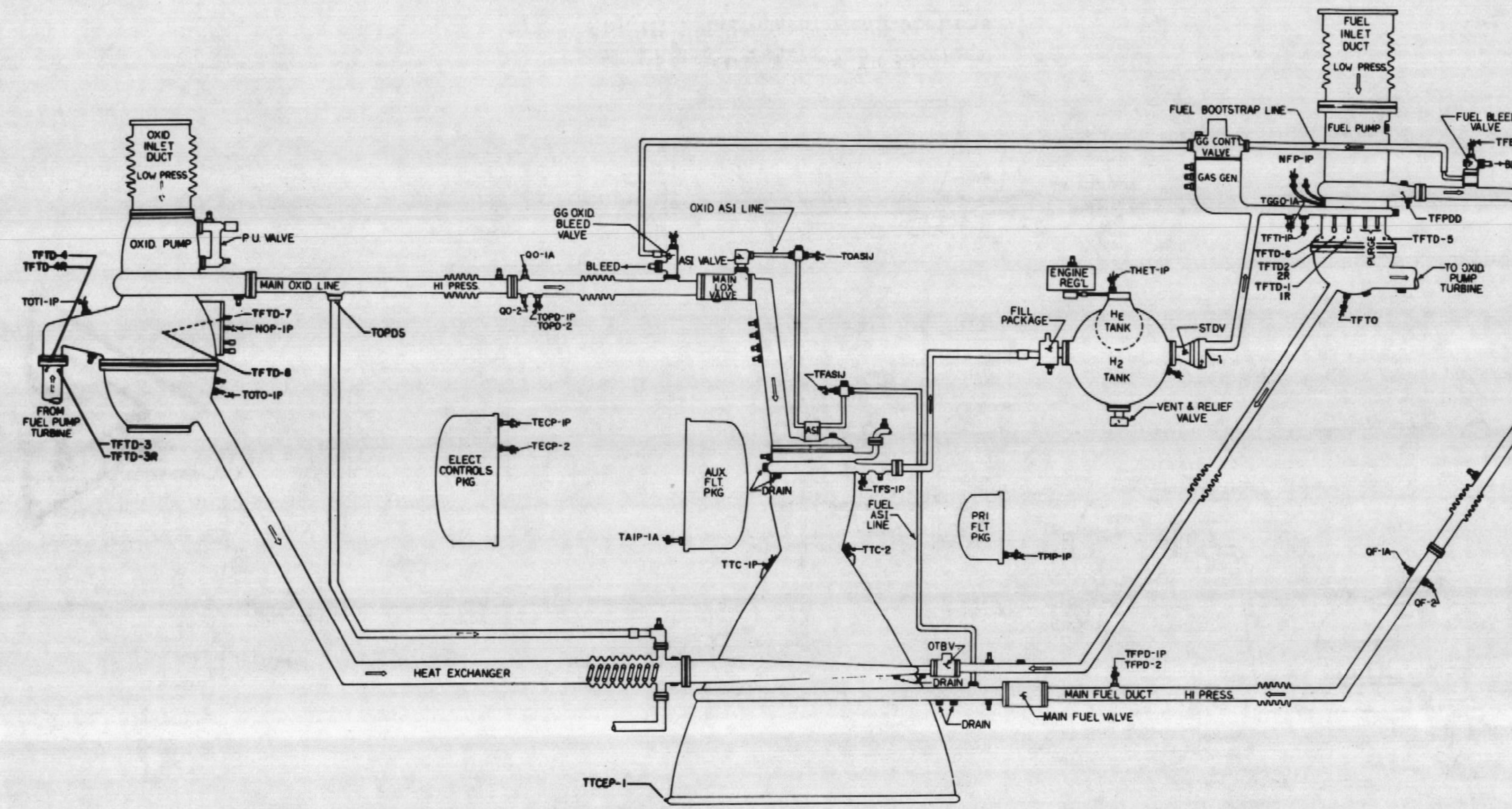
TABLE III-1 (Concluded)

AEDC Code	Parameter	Tap No.	Range	Micro-SADIC	Magnetic Tape	Oscillo-graph	Strip Chart	X-Y Plotter
	Temperatures		**°F**					
TSC2-15	Thrust Chamber Skin		-300 to +500	x				
TSC2-16	Thrust Chamber Skin		-300 to +500	x				
TSC2-17	Thrust Chamber Skin		-300 to +500	x				
TSC2-18	Thrust Chamber Skin		-300 to +500	x				
TSC2-19	Thrust Chamber Skin		-300 to +500	x				
TSC2-20	Thrust Chamber Skin		-300 to +500	x				
TSC2-21	Thrust Chamber Skin		-300 to +500	x				
TSC2-22	Thrust Chamber Skin		-300 to -500	x				
TSC2-23	Thrust Chamber Skin		-300 to +500	x				
TSECP	Engine Control Package Skin		-50 to +250	x				
TSGGOC	Gas Generator Opening Control Port		-350 to +100	x				
TSOB	Oxidizer Bootstrap Shroud Skin		-200 to +100	x				
TSOVAL-1	Oxidizer Valve Closing Control Line		-200 to +100	x				
TSOVAL-2	Oxidizer Valve Closing Control Line		-200 to +100	x			x	
TSOVC-1	Oxidizer Valve Actuator Cap		-325 to +150	x				
TSOVC-2	Oxidizer Valve Actuator Filter Flange		-325 to +150	x				
TSPIP	Primary Instrument Package Skin		-50 to +250	x				
TSTC	Start Tank Conditioning		-350 to +150	x				
TSTDVOC	Start Tank Discharge Valve Opening Control Port		-350 to +100	x				
TTC-1P	Thrust Chamber Jacket (Control)	CS1	-425 to +500	x				
TTCEP-1	Thrust Chamber Exit		-425 to +500	x				
TXOC	Crossover Duct Conditioning		-325 to +200	x				
	Vibrations		**g's**					
UFPR	Fuel Pump Radial 90 deg		±200		x			
UOPR	Oxidizer Pump Radial 90 deg		±200		x			
UTCD-1	Thrust Chamber Dome		±500		x	x		
UTCD-2	Thrust Chamber Dome		±500		x	x		
UTCD-3	Thrust Chamber Dome		±500		x	x		
U1VSC	No. 1 Vibration Safety Counts		On/Off			x		
U2VSC	No. 2 Vibration Safety Counts		On/Off			x		
	Voltage		**v**					
VCB	Control Bus		0 to 36	x		x		
VIB	Ignition Bus		0 to 36	x		x		
VIDA	Ignition Detect Amplifier		9 to 16	x		x		
VPUTEP	Propellant Utilization Valve Excitation		0 to 5	x				



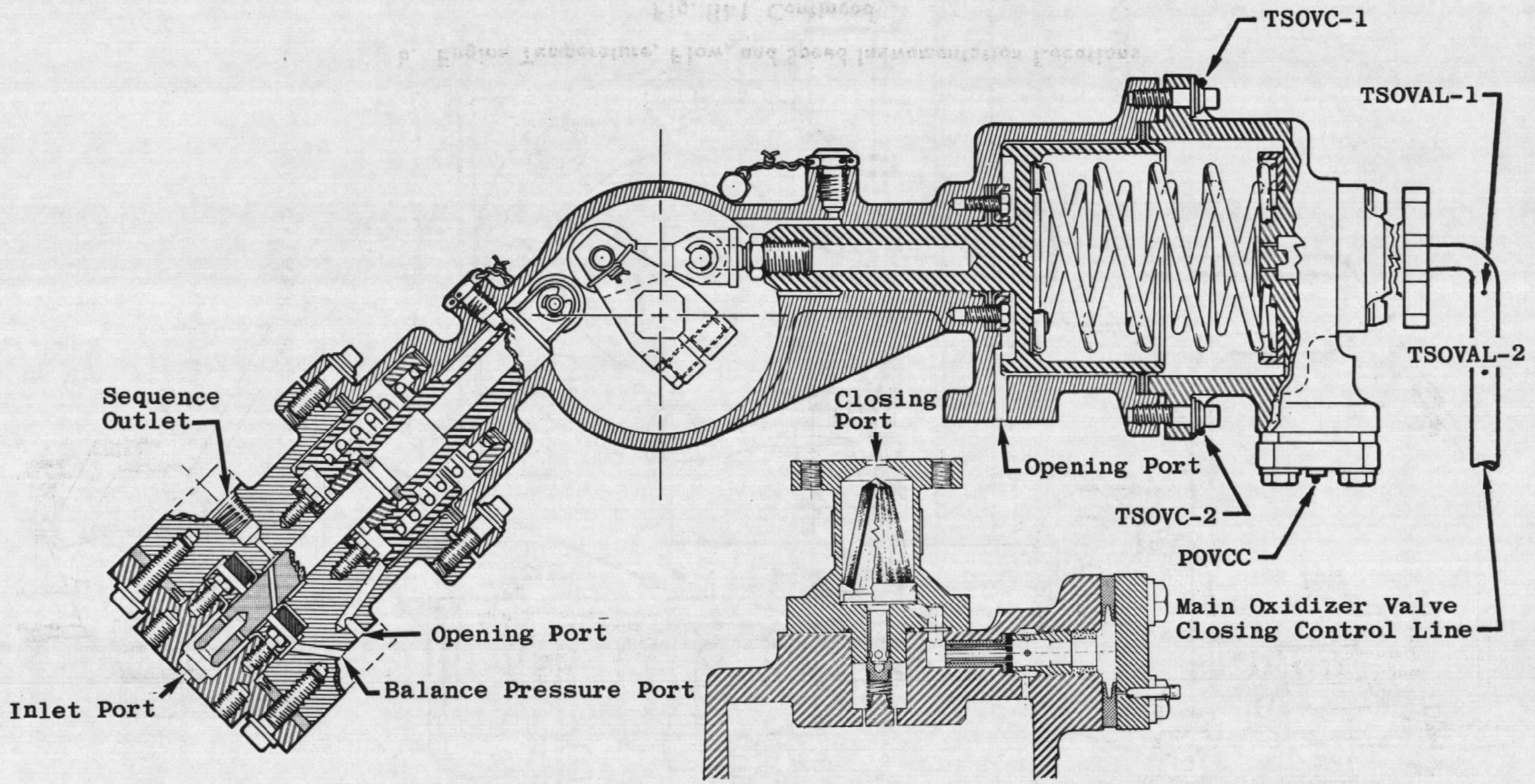
a. Engine Pressure Tap Locations

Fig. III-1 Instrumentation Locations

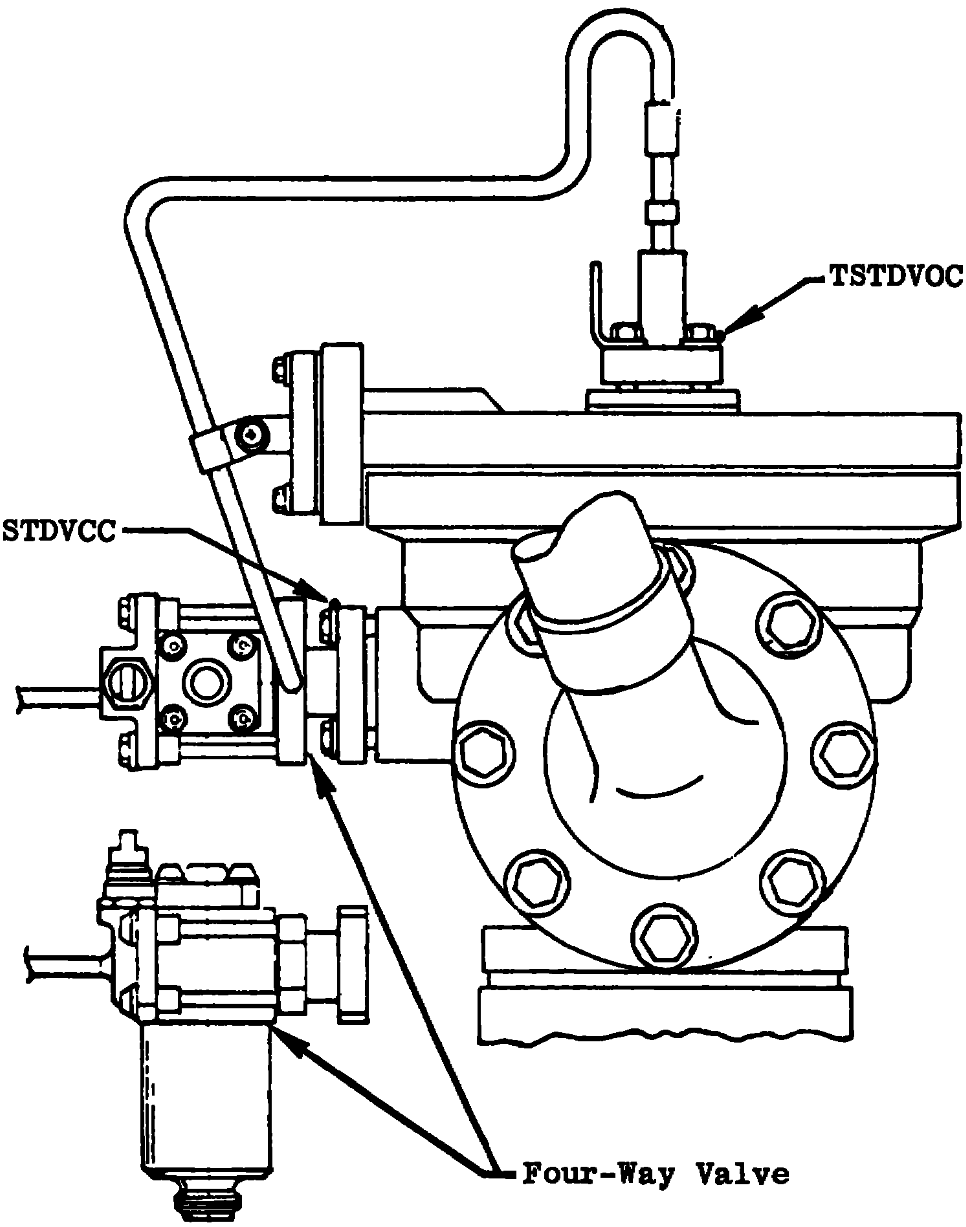


b. Engine Temperature, Flow, and Speed Instrumentation Locations

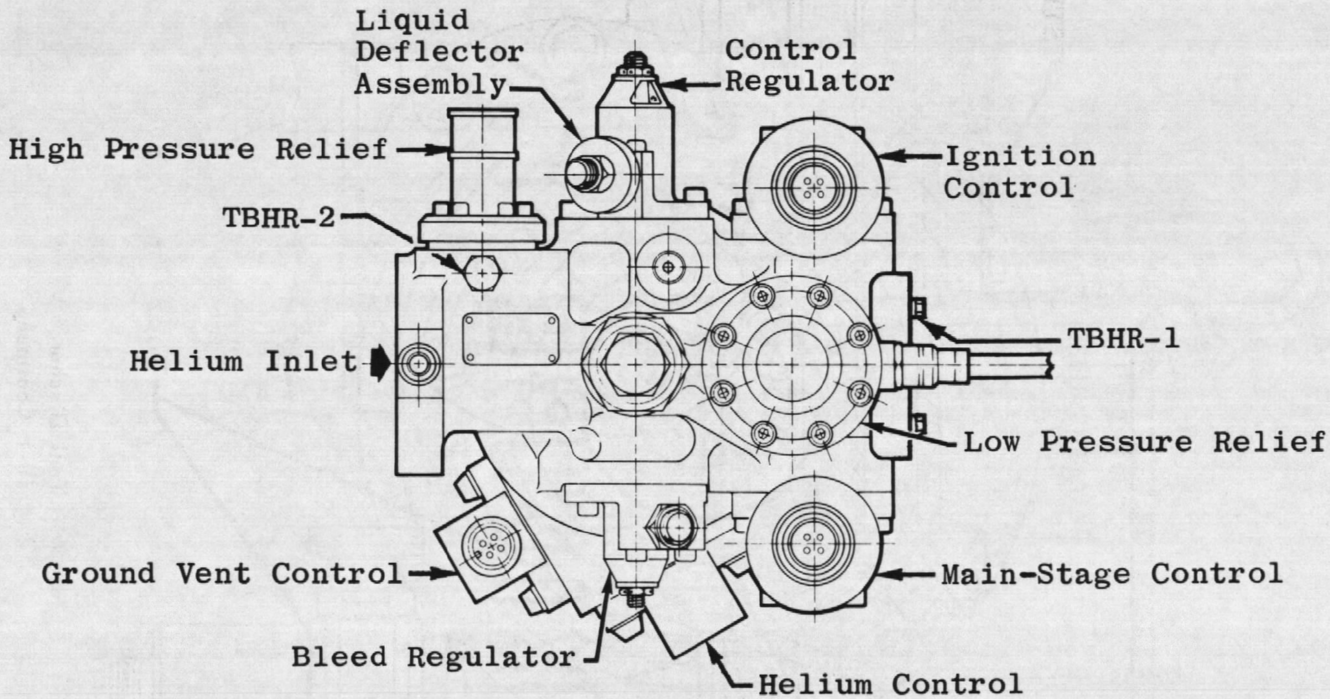
Fig. III-1 Continued



c. Main Oxidizer Valve
Fig. III-1 Continued

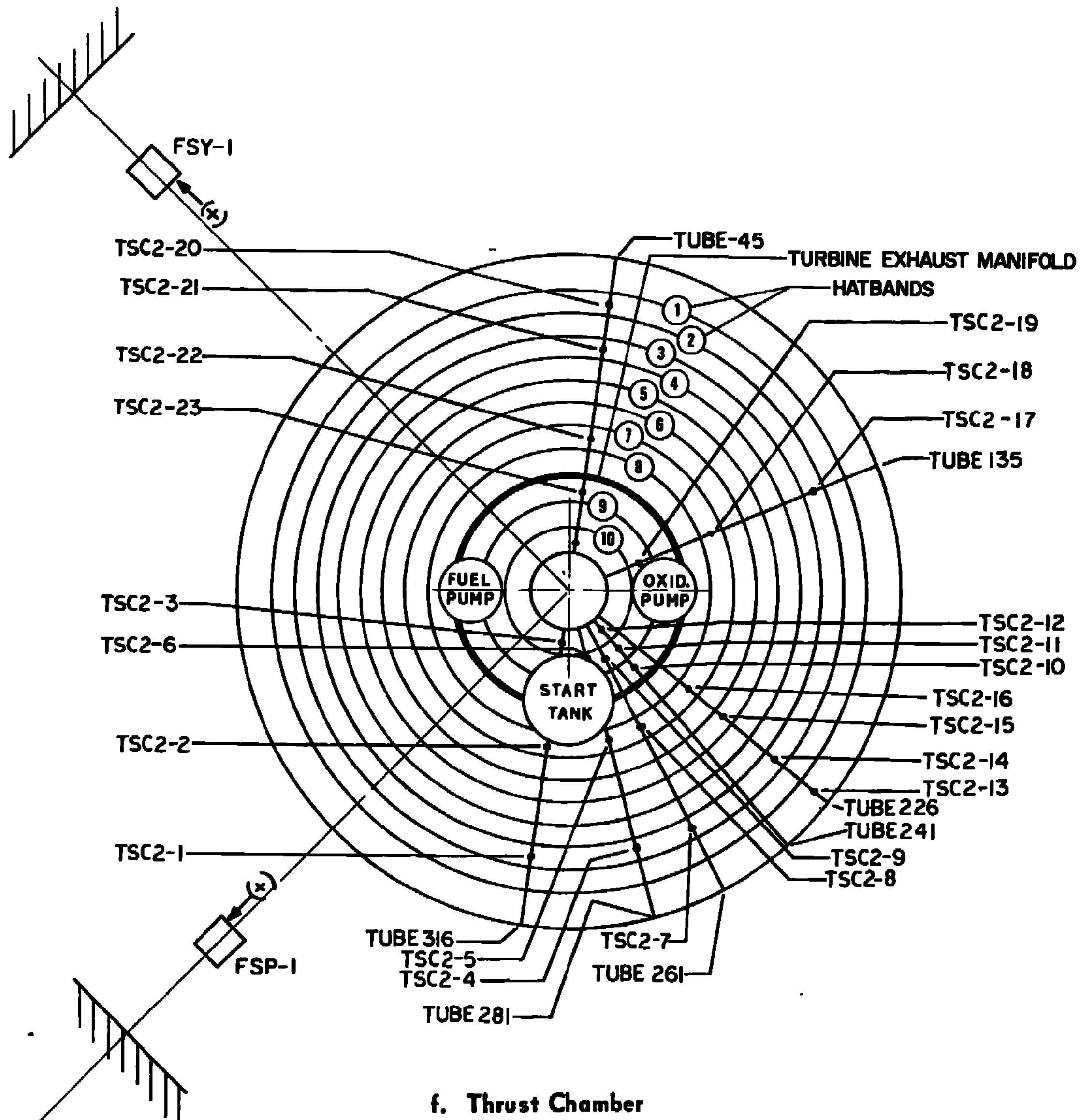


d. Start Tank Discharge Valve
Fig. III-1 Continued

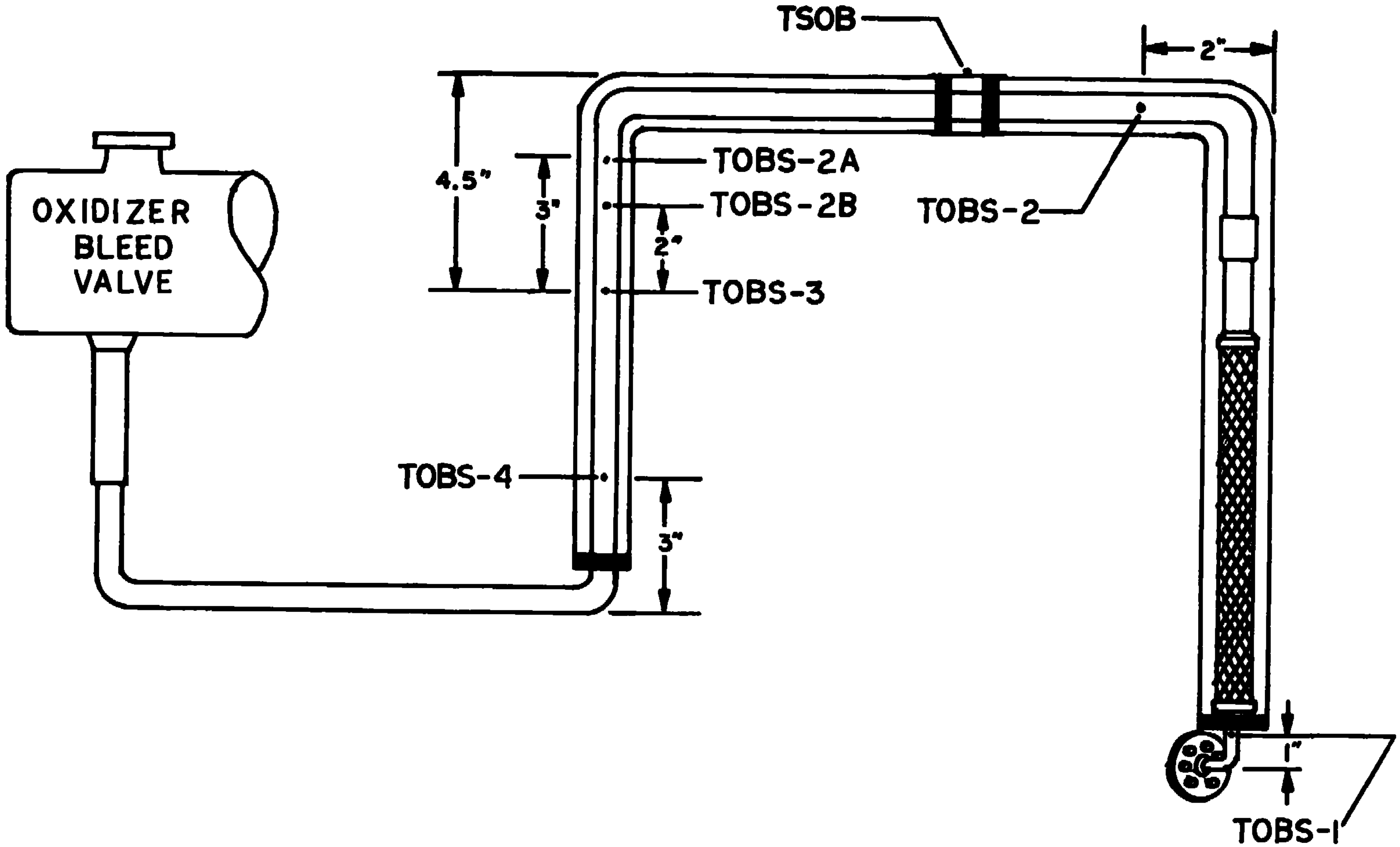


Top View

e. Helium Regulator
Fig. III-1 Continued



f. Thrust Chamber
Fig. III-1 Continued



g. Oxidizer Bootstrap Line
Fig. III-1 Concluded

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4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

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13 ABSTRACT

Two nonfiring tests of the Rocketdyne J-2 rocket engine were conducted on September 15, 1967, in Propulsion Engine Test Cell (J-4) of the Large Rocket Facility, Arnold Engineering Development Center. The tests were accomplished during test period J4-1801-09 at pressure altitudes from 97,000 to 106,000 ft. The objectives of the test included the determining of the magnitude of any side forces generated by the flowing of propellants through the engine under propellant tank ullage pressure.

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14. KEY WORDS	LINK A		LINK B		LINK C	
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altitude tests						
propellants						
side forces						
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